ANNALS OF SURGERY

VOL. 114 AUGUST, 1941 No. 2

THE COOPERATION BETWEEN THE ARMY SERVICES OF EVACUATION AND HOSPITALIZATION*

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AN ACTIVE, intelligent cooperation predicates a basic knowledge of the objects desired, the mechanism by which they are to be accomplished, the type, character and training of the personnel to be employed, and an estimate of the probable difficulties that will be encountered.

It has been said, that the Army must change its tactics every ten years or suffer defeat. Since the last war, military tactics have undergone momentous changes. The present war has become one of mechanization and movement. The speed of the attack, the greater use of automatic weapons, combined with the moral and physical threats of an airplane attack, has greatly increased the difficulties of the Medical Department. Undoubtedly, the brunt of these difficulties will fall upon the collective, evacuation, and advance hospital services. Though the technic of triage, surgical management, and evacuation will necessarily be adapted to recent tactical concepts of mechanization and movement, the principles governing these matters will remain unchanged.

In the last war, the theater of military operations assumed the traditional fan-shaped pattern, the greater activity being in the periphery of the fan. In sharp contrast to this old pattern, the present military activities extend from the firing line to the home and beyond. In addition to this change of pattern, the tempo of all military activities has been speeded up. The attack is now designed to destroy the nation's vital resources before its full power can be mobilized; thus the defense of the home sector presents the Medical Department with a new problem. It is fair to assume that the Army staff has already worked out a master plan to meet such a situation. Have we as a body of surgeons given thought to such a possibility, have we considered how we can cooperate?

The first principle of military strategy is to assume the worst possible conditions, and then plan to meet them. It seems self-evident, that the only way to cover the medical situation arising in a total attack would be to

* Read before the American Surgical Association, White Sulphur Springs, W. Va., April 29, 1941.

mobilize the surgical and allied professions for the duration of the war. The acceptance of nationalization in such a crisis should become a duty and a privilege for us all.

An open slashing attack will have to be met by an equally mobile defense. It can be readily seen that the increased use of automatic weapons will lead to a more extended firing line, and every foot of extension will add to difficulties and dangers of the divisional collecting service. Some of these units will have to be furnished with protective armor, and the forward evacuation service will have to be provided with a motor equipment that can negotiate the roughest terrain.

In all probability, there will be an insufficient number of regular medical officers to fill all the executive surgical positions, and many of our profession will have to be assigned to such positions. If they are to function efficiently in the Army zone, they must have an elementary knowledge of what the military authorities expect of them.

Professional Peculiarities.—All physicians, by the nature of their calling, are individualists. Much of our time and energy is devoted to making our patients follow orders. Subconsciously, we assume the attitude of command and without knowing it we become benevolent martinets. In all fairness to the rank and file of the profession, it must be confessed that the same tendency has been encountered in the professorial ranks and this often in a distinctly unpliable form.

The active surgeon enters the service as a tried veteran in his life's work. Herein lies his advantage and his great military value. His surroundings have changed, but not his work. The civilian surgeon, anxious to give his best, must slough off the attitudes of the lone wolf and the commanding general, and cheerfully accept the vital military principle of coordinate control. The intelligent practice of this principle will unconsciously smooth out many rough spots in his adjustments to the new life. The mastery of this principle will automatically increase his surgical and military value, but above all it will enrich his own and his corps morale. Morale though intangible is the very soul of a successful army.

A study of what happened to our wounded in the Civil War shows in a most remarkable manner how history repeats itself. In the early years of the Civil War, the evacuation service was woefully inadequate in organization, equipment, and personnel. Very little improvement occurred until Letterman came on the scene. By 1864, the great value of a well-equipped evacuation service had been learned, and we find General Grant crossing the Rapidan with an Army of 73,000 men and 500 ambulances; that was one ambulance for every 146 men. If the First Army of the American Expeditionary Forces had anything like such a proportion, what a joy and a blessing it would have been.

The First Army: Meuse-Argonne Offensive.—The First Army contained more than 1,031,000 men. This is the largest single Army that the world has ever known. When the battle opened September 26, 1918, the Army

had 400 ambulances. Faced with such a shortage, it was vital that plans be devised to keep every wheel moving. In order to make the medical transportation liquid, all trucks, ambulances, motorcycles, *etc.*, were pooled and placed under the control of the ambulance director. The results obtained bore out General Sherman's famous dictum: "The more simple the principle, the more likelihood of determined action."

From a military standpoint, the care of the lightly wounded and their prompt return to their own combat units is a matter of paramount importance. Personnel trained under fire are of far greater value to a commanding general than raw replacements from the depot. General Sherman was so convinced of this, that he carried many of this type of wounded in his wagon trains in preference to hospitalizing them.

The experience of the last war taught that 20 to 25 per cent of the wounded brought to the evacuation hospitals could be returned to duty in less than a week, and an additional 20 to 30 per cent who pass through the evacuation hospital will be able to return to duty within ten to 12 days. The first group will consist of the exhausted, the pseudogassed, and the lightly wounded. This group should be promptly evacuated to the nearby Army convalescent hospital, and from there to the Army replacement depot for forwarding to their combat units. The second group should be evacuated to the nearest general hospital in the zone of communications, with the express purpose of their prompt return to their combat units. The remaining wounded should be evacuated to the zone of the interior.

Evacuation Hospitals.—The evacuation hospital is the pulsating heart of the evacuation system, and it is the direct responsibility of the surgical director and the surgical teams to see that a bottleneck does not occur. If you have ever had the misfortune to see one of these bottlenecks, you will never forget it. They did occur.

The evacuation hospital service must plan for the prompt clearing of the incoming ambulances with the exchange of splints, stretchers, blankets, *etc.*, and be prepared in a like manner for an outgoing evacuation. Great delay was experienced at some of the Army hospitals due to the poor provisions made for this essential service. The ambulance drivers were quick to sum up the efficiency of the hospitals in terms that were endearing and otherwise. They alluded to the hospitals as the outfits of Longshanks, Fats, Slats, Valentino, and Weasel Face. Perhaps some of the members can identify one of our honored Fellows, who bore the endearing title of Longshanks.

The Handling of the Lightly Wounded in the Army Hospitals.—The evacuation service of the Army felt keenly that entirely too many unoperated cases were evacuated. In the first phase of the offensive 11,370 men, supposedly simple cases, were potential sources of trouble, through the possibility of their wounds becoming infected. Reports from the rear soon showed that our fears were well-grounded.

This poor operative output was due to the inexperience of many of the teams in this field of work, and to the inherent difficulty of making profes-

sional men think of the wound in terms of military value, rather than in terms of professional interest. In the majority of evacuation hospitals, the organization and facilities for handling this important class of wounded were very defective. The chief surgeon of the Army, realizing the urgency of the situation, instituted radical changes in the handling of the lightly wounded. The lightly wounded were retriaged, assigned special roentgen ray equipment, special operating rooms, special surgical, splint, and anesthesia teams. Experienced surgeons of good judgment who thought and acted quickly were selected. The slow careful operators were assigned to other types of cases. The newer anesthetics, well-selected, will be a very important factor in facilitating this important work.

The Lightly Wounded Production Line.—This line was operated on the system of three to four tables to a surgeon. Its practical value soon became apparent. In the second phase of the offensive, only 293 unoperated cases were evacuated. The perfection of this method was due to Lt. Colonel George Davis, of Chicago, and his able assistant, the late Major Sherbondy. Some of the teams cleared 80 to 100 and more cases in their shifts. Colonel William Darrach was energetic in spreading the gospel of this method and in this he was ably supported by Lt. Colonel Marshal Clinton. The surgical staff of the First Army can justly feel proud of the result obtained. It has not been matched in our Army, or in any of the Armies of our Allies.

Every evacuation hospital should be simply but adequately equipped and its personnel thoroughly trained in the functioning of the lightly wounded production line. The first requisite is an ample floor space. Dinky little trailer and automotive operating rooms are next to useless, and not worth the gas they use. If suitable space is not obtainable in permanent buildings, experience has shown that there is nothing better than well-arranged tentage; in fact it is ideal for the smooth functioning of the lightly wounded production line. The roentgen ray and sterilization equipment can be of the automotive or portable types, or a combination of both. In this way, the production line can be geared to meet any situation. Simplicity, direct action, and coordination are the driving power of the line.

Liaison.—One of the most difficult ambulance problems in the big offensive is to insure an even distribution of the wounded to the Army hospitals. Its solution is only possible when there is the closest active coordination between the director of the corps ambulances, the director of the Army ambulances, and the evacuating officer of the Army hospitals. Fortunately, in the First Army, this relation was intimate. The technical working from the side of the Army was facilitated, as one individual was the consultant in surgery for the First Army, and in addition he held the interlocking positions of director of the evacuation of the wounded and the director of the Army ambulances.

The sound judgment, the tireless energy, and the splendid whole-hearted spirit of coordination displayed by the divisional and corps ambulance directors made the seemingly impossible, possible. Certain definite hospitals were

assigned by the chief surgeon for the wounded of each corps. In the main, this was a wise provision, but there were times when the Army found it necessary to make a rapid readjustment to meet the exigencies of the moment.

All deficiencies in divisional ambulances were filled up through lending sections to the corps, and in addition a section from the Army reserve was attached to each corps. They took care of its local emergencies. The main Army ambulance reserves were parked in echelon: The first, one hour from the line, the second, two hours from the line. In this way, the reserves could be readily shifted from one corps to another as the circumstances required.

Secondary Duties of the Ambulance Service.—A maintenance of a motor courier service for liaison purposes, the rationing of the French trains, daily forwarding of medical supplies, *etc.*, were performed by the ambulances returning to the front. Some of the evacuation hospitals and special hospitals entered the Army without motor transport. These had to be moved and serviced with medical supplies, rations, fuel, *etc.*, and in a few cases with water; the transportation of surgical teams, nurses, and medical personnel, baggage, *etc.* Forty-three hundred passengers were carried during the offensive.

Road Control in Reference to the Evacuation of the Wounded.—In the Army zone, certain roads were assigned to the division, the corps, and the Army. The type of transportation and its direction were under the immediate control of the military police, and their word was law. Daily reports of the roads to be used, their condition, danger zones and maps, indicating all changes in position and direction, were furnished the ambulance director. (See "The Report for the Evacuation of Wounded in the Meuse-Argonne Offensive.")

Directional Signs for the Evacuation Hospitals and Their Importance.—The name of the hospital with a directional arrow should be displayed in large plain letters on a sign of adequate size. These signs should be placed at key points along the corps and Army roads. The signs should be illuminated at night, so that the ambulance driver will know at a glance where he must go. Driving without lights on a dark rainy night, along unknown roads, is a difficult and uncertain task. In the early phases of the offensive, until the road control was perfected, the lost and wandering ambulance with its load of wounded was demoralizing.

The Bedevilment of the Ambulance Drivers and the Mixing Up of the Corps Wounded.—In the opening days of the offensive, a few overenthusiastic commanders of evacuation hospitals, without authority, placed road signs directing the ambulance drivers to their hospitals. Unfortunately, they did not confine their activities to their own corps area, nor did they consult the military police; in fact they successfully succeeded in throwing a monkey wrench into the evacuating system which led to the overcrowding of certain hospitals. The bedeviled ambulance drivers were like lost souls, trying to find a resting place for the weary wounded. Fortunately, the mix-up did not

last long, the military police discovered the trouble, and promptly ripped down every unauthorized sign.

Consultants.—It is imperative that the consulting service should prepare definite plans well in advance of any offensive. They should weigh carefully the effect of their policies on the service of evacuation and hospitalization. It is extremely difficult for the civil surgeon, without military experience, to grasp how closely these two services are integrated and what a confusion can be caused by last-minute changes. The surgeons with a few alert medical men grasped this principle and put it to practice, while other medical consultants preferred to sleep and dream. Some of them are still sleeping.

The Army Consultant.—The Army consultant must be more than an individual diagnostician and his vision must not be dimmed by the eyeglasses of specialism. He should be a surgeon of from 40 to 45 years and no older. Men of more mature years with active minds and vision should be attached to the zones behind the Army as general consultants. Here their talents will be of greater value to the wounded. A knowledge of the rudimentary military principles will enhance value of all consultants.

In the First Army, the consultants endeavored to bring into the office of the chief surgeon information that would be of value to him in the improvement of the professional care of the wounded and, at the same time, to furnish him with the detailed information regarding the proper care of the patient in the divisional and corps areas.

The reports showed that there were considerable differences in the evacuation time of the divisions; that is, the time that elapsed between the wounding of the patient and his reception in the Army hospitals. The reports from the Army hospitals showed that the best results in cutting down infection and saving life were obtained by those divisions which, in spite of all difficulties, managed to get their cases back in good time. The marked difference between some of the divisions was due to the fact that there was a tendency in certain of them to hold the case for operation. The condition of the roads failed to explain the marked discrepancy between the divisions. There were certain divisions which from the moment they entered the Army area till they left, managed to get their cases back on time.

Special Surgical Hospitals.—Experience had taught the First Army that it was impracticable, wasteful, and harmful to attempt to triage selected wounded for individual specialty hospitals. In order to function efficiently, these hospitals had to be provided with a special evacuation service. The Army evacuation service, faced with an acute ambulance shortage, felt that such a waste of ambulances was not justified. To still the persistence of a well-meaning consultant, who desired the establishment of a specialty hospital, a tentative trial was undertaken by the chief surgeon of the Army. It proved to be a miserable failure. In the zone of communication and the interior, the separate specialty hospital is a very valuable asset, but in the combat zone, it is simpler and more practicable to install special operating teams in the evacuation hospitals.

The Hospitalization of the Nontransportable Wounded.—Experience showed that large hospitals were not necessary. A small hospital of about 50 beds and two surgical teams is all that is required provided the hospital is strictly limited to this class of wounded. The hospital should be located close to the divisional triage center so that the direct lettering of the wounded is possible.

In the larger hospital, there was a distinct tendency by ambitious surgical teams to fill the empty beds with operative cases. In fact, some of the units became baby evacuation hospitals and the clearing of these hospitals added another unnecessary burden to the overwrought motor transport of the front.

The present surgical hospital has 400 beds. They are assigned one per front-line division and they are placed in immediate support of the divisional clearing station. As they are not motorized, the Army furnishes the transport. In the last war, this high-sounding phrase was heard not infrequently by the evacuation service. It was a headache and meant "George, you do it." And George had "to do it."

The Peddling of the Wounded.—No well-organized evacuation hospital should ever refuse admittance to the wounded. To force the ambulance driver to peddle the innocent wounded is a detestable practice. We consider it the lowest form of the abuse of power.

CONCLUSIONS

(1) The basic principles of all military surgery is débridement. Chemotherapy and immobilization in plaster are adjuncts. The more extended use of the roentgen ray and the employment of the newer anesthetics should greatly extend the usefulness of the military surgeon. (2) An efficient evacuation and hospitalization is the backbone of all treatment; without it, surgery is hamstrung. (3) On the proper triage, adequate motor transport, and the will to see it through rests the success of the evacuation of the wounded. Undoubtedly, a well-developed airplane transportation will become a very valuable asset. (4) The evacuation of the wounded will always be a difficult and complicated task of great responsibility. As surgeons, it should be our duty and our pride to see that the stream of wounded flows steadily onward without a check. (5) As individuals, we are apt to be dogmatic, and it is difficult for us to accept the principle of coordinate control.

I am convinced that we all can profit by Oliver Cromwell's admonition: "My brethren by the Bowels of Christ I beseech you, bethink you that you may be mistaken."

DISCUSSION.—DR. MORRIS K. SMITH (New York, N. Y.): Doctor Lyle speaks with particular authority on the subject about which he has addressed us. After holding various posts of increasing responsibility in the last war, he was, during the Meuse-Argonne offensive, director of ambulances and evacuation of the wounded and chief consulting surgeon of the First Army. In this campaign 126,000 sick and wounded were evacuated to the railhead hospitals. I would urge that those of you who may be anticipating service in the front areas, should we enter this war, study thoughtfully what he has to say.

It appears inevitable that campaigns characterized by the increased mechanization

and mobility that has so far marked the present conflict should offer new and more difficult problems in the evacuation and hospitalization of the wounded. What little I have been able to find in the literature on the subject emphasizes an increased need of coordination in the medical services and a greater supply of ambulances. The underlying principles of efficient evacuation and prompt and competent handling of the wounded man remain the same, however. To these ends, Doctor Lyle's experience affords valuable lessons.

The civilian surgeon who finds himself in front area field service in war has to realize that evacuation of sick and wounded rather than treatment is his primary responsibility. In times of activity its smooth functioning is dependent on well-coordinated efforts from regimental medical service down the line. It is important that the supply of ambulances be adequate and efficiently utilized.

At the evacuation hospitals, a blockade can easily arise. Doctor Lyle stresses particularly the importance of separate teams, with their own assignment of roentgen ray equipment and operating units, for the handling of the lightly wounded. This facilitates prompt treatment and rapid turnover for this large group who are, as he points out, from the Army standpoint the most important, because of the possibility of their early return to duty. To this end, they should be evacuated to nearby convalescent and replacement areas rather than to distant hospital centers.

Doctor Lyle has found special surgical hospitals in the front areas impracticable. He also feels that front area units for nontransportable wounded should be small.

In the hospitals, well away from the combat area, where continued treatment of the sick and wounded is planned, the erstwhile civilian surgeon will find new problems which will challenge his professional skill, because the types of injury will be different from those to which he is accustomed at home. But, none the less, he will be in an hospital environment, his familiar workshop. In the front areas, he must adjust himself to greater changes. There the problem is collecting, sorting out, and sending on the wounded and sick. In the evacuation hospitals, the surgeon will be doing primary surgical treatment but he must cope with the reception, handling, and evacuation of large numbers of patients in the shortest possible time. Careful planning and disciplined performance of duties are essential.

Dr. William Darrach (New York, N. Y.): I should like to speak on the treatment of compound fractures but, unfortunately, I have another thought which I want to emphasize, and that is that if we are going to live up to the function of the Medical Department we have to be hard-boiled. The function of the Medical Department is to maintain the fighting strength. If we are going to live up to that, we should concentrate our major efforts on those wounded who can be and may be returned to the fighting forces.

That means that all the special groups, the highly trained and efficient compound fracture surgeons, the maxillary, the head surgeons, the chest surgeons, the belly surgeons, belong not to the main function of the Medical Department, but to their secondary purpose of humanitarian care of those who are severely wounded and who never will go back. We cannot omit handling those people, because part of our duty is to maintain the morale. If we were strictly hard-boiled, we would pay attention only to the lightly wounded. We must pay some attention to the severely wounded, but they should be of secondary importance. Therefore, I think that if the idea that was carried out in a small way, but sufficiently to prove that it can be done, by Joe Davis and Sherbondy and one or two other attempts, whereby the lightly wounded can be handled at the rate of five or six an hour, instead of one case per hour, as most of us were doing on the heavier cases, were really carried out we would find that our Medical Corps work was more efficiently done, and we would restore more men to the fighting forces.

I had one brief experience of almost eight hours of doing this work with the British Clearing Station No. 47. In taking these lightly wounded cases, we could do about four or five an hour there, but the next day the commanding officer came around and said, "I am sorry, but this is not done in the British Army," so we stopped.

Again, in the first corps, there was an excellent plan made for putting an Evacuation Hospital up fairly close, where the lightly wounded could be handled at this rate of rapid production and kept in that area and sent back, but unfortunately for that scheme Armistice came along and spoiled it. I would like to see that scheme put into effect, and that the major function of the Medical Department be recognized as restoring the fighting forces.

THE DIAGNOSIS AND TREATMENT OF CARDIAC TRAUMA*

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ALTHOUGH the suture of heart wounds is classed as an attainment of modern surgery, a knowledge of their fatal outcome, if untreated, has been recognized from the earliest times. For the student interested in the history of cardiac surgery, an interesting point of departure would be the Iliad and the Odyssey, for the Homeric stories abound with reference to cardiac wounds. Hippocrates[1] realized their fatal nature, as did Paré,[2] who described them, but made no suggestions regarding their treatment.

Boerhaave[3] stated that all wounds of the heart were mortal. Hunter made no mention of the subject, and John Bell,[4] in his "Discourses on the Nature and Cure of Wounds," devoted only two paragraphs to the subject, although he recognized the signs and symptoms of the condition and cited two patients who lived several hours, who might well have been saved by operation. He thus discussed the subject: "There is so little to be done . . . and the signs and consequences are so clear, that it were a waste of time to speak longer of wounds of the heart." Billroth,[5] who dominated the surgery of his day, wrote (in 1875): "Paracentesis of the pericardium is an operation which, in my opinion, approaches very closely to that kind of intervention which some surgeons would term a prostitution of the surgical art and other madness." He did add, prophetically, "Perhaps another generation will think otherwise about it." As late as 1896, Stephen Paget[6] wrote: "The surgery of the heart has probably reached the limits set by nature to all surgery; no new method and no new discovery can overcome the natural difficulties that attend a wound of the heart."

Two figures stand out because of their disagreement with these pessimistic pronouncements; Morgagni[7] who, in 1761, showed that blood in the pericardium compressed the heart and embarrassed its movements, and Baron Larrey[8] (Napoleon's great surgeon) who decompressed a wounded heart by drainage, and who demonstrated by experiments on dogs that these injuries were not necessarily fatal.

Modern surgery of the central circulatory system began with Roberts[9] (1881), who suggested that wounds of the heart be sutured. Block[10] (1882) successfully sutured the hearts of rabbits, but de Vecchio [11] (1895) deserves greater credit for demonstrating to the Eleventh International Medical Congress, at Rome, the healed wound in a dog's heart. Within a year the human heart was sutured by Cappelen[12] (September, 1895), by Farina[13] (March, 1896), and Rehn[14] (September, 1896). Rehn's patient survived. By 1909,

* Delivered on the occasion of the receipt of the Matas Vascular Surgery Award, Tulane University, New Orleans, La., November 14, 1940.

Peck[15] was able to collect 161 cases treated surgically, with a mortality of 63 per cent. Pool[16] (1912) added 79 cases, with a mortality of 49 per cent; Smith[17] (1923) collected 25 cases, with a mortality of 36 per cent; and Bigger[19] (1932–1933) added 70 instances, with a mortality of approximately 30 per cent.

The percentage of reported recoveries is unquestionably too high, because of the fact that many single, favorable cases have been reported, whereas those ending fatally are not so likely to be recorded. At any rate, the percentage of recoveries is at the present time at least 50 per cent, whereas only 10 per cent of the untreated cases reported by Fischer[20] (1868) recovered.

Incidence.—Wounds of the heart are relatively rare. In southern hospitals they comprise about 0.1 of 1 per cent of patients. At Emory University, 2 per cent of the penetrating wounds of the chest injured the heart. Considering its size and exposed position, it is surprising that it is not more frequently injured. If those patients were considered who die of homicide, suicide, and accident, but never reach the operating room or the autopsy table, it is probable that the percentage would be much higher. Moreover, the diagnosis is frequently overlooked, and patients may die without surgical intervention who might otherwise have been saved had early diagnosis been made and prompt surgical intervention undertaken. That cardiac wounds are more frequent than is generally supposed is evidenced by the ever-increasing number that are reported. At Emory University, the number of patients treated for wounds of the heart has increased steadily each year since 1930. This is merely another evidence of a better ability to diagnose the condition, since the number of chest injuries has decreased.

Mode of Injury.—For the most part, penetrating wounds of the heart are produced with homicidal or suicidal intent, and, therefore, knives, ice-picks, and pistols are the most frequent weapons with which the injury is inflicted. In addition, the heart may be wounded in crushing injuries or by its accidental penetration by glass and splinters as a result of automobile accidents. Aside from penetrating wounds, contusions of the heart, fatal or nonfatal, may occur. In any event, early diagnosis and treatment is necessary since delay is rapidly fatal.

Cardiac Tamponade.—Rapid changes in pressure relationships, particularly within the pericardium, affect the filling and emptying of the heart and, if unrelieved, will quickly bring about a standstill of the cardiac mechanism. The diagnosis of acute cardiac compression, the removal of its cause, and the prevention of its recurrence, is the basis for the treatment of cardiac injuries.

Normally, the intrapericardial pressure is less than that of the atmosphere, and the pressure in the intrathoracic portions of the venae cavae is probably negative. With the rapid accumulation of fluid in the pericardium, as from pus or blood, the venous pressure rises, and after it reaches a height sufficient to overcome the increased intrapericardial resistance, blood enters the heart, and the circulation continues. Normally, the venous pressure ranges between

75 and 120 Mm. of water. In rapidly increasing accumulations of fluid, the pericardium cannot distend sufficiently nor can the venous pressure rise to such a level as to allow the filling of the heart for any length of time. However, I have noted a venous pressure as high as 400 Mm. of water in acute compression of the heart, and have seen this pressure maintained for as long as 30 minutes without a fatal result. Where the tamponade of the heart is gradually produced (serous effusion), the pericardium is slowly distended and a high venous pressure will maintain the circulation for days.

Acute tamponade leads to cerebral anemia, for the heart can no longer fill. Release of tamponade is, therefore, a matter of first importance, and demands immediate treatment. The symptoms are a low or unobtainable arterial pressure, a high or rising venous pressure, and a quiet heart. The pulse is weak or absent, and the veins, particularly those of the neck, are prominent and strutted. Because of the venous stasis there is a marked cyanosis of the lips and tongue.

Diagnosis.—Because of its position in relation to the anterior chest wall, a wound of the right ventricle is more frequent, but wounds of all four chambers as well as those of the intrapericardial portions of the great vessels may be encountered. The exact location of the wound can only be surmised before operation, since symptoms from bleeding or tamponade will be the same, regardless of the location. Death may occur from rapid loss of blood either into the chest or to the outside, but death is more likely to occur as a result of tamponade.

The history is usually characteristic. There is freedom from symptoms for several minutes after the injury, followed by exhaustion, and then loss of consciousness. Either stupor or wild delirium may follow. Patients have been known to walk several blocks or to continue fighting for as long as five minutes after a wound of the heart. Bleeding is profuse at first, but soon stops. This train of symptoms is due to a rapidly increasing tamponade. When the heart is wounded, it bleeds freely to the outside and usually into the pleural cavity as well. At the same time, some blood collects in the pericardium and when 100 to 200 cc. have so collected, the heart becomes compressed. Contractions become weak, and bleeding to the outside stops. With the rise in intrapericardial pressure, the venae cavae can no longer convey normal quantities of blood to the heart, and cerebral anemia, as evidenced by unconsciousness, results.

The position and direction of the wound may aid in diagnosis, but the course of a bullet, or even a knife thrust, is notoriously misleading, although those near the left of the sternum from the second to the fifth interspaces are most apt to injure the heart.

Accurate diagnosis, above all, will depend to a large extent upon the Resident Staff, who must be trained to be ever on the alert not only to recognize symptoms of cardiac trauma, but to suspect every chest injury as a potential heart wound. All too frequently, wounds considered inconsequential

may later prove to be fatal. This is particularly true in a case where an ice-pick has caused the wound.

The skin is usually cold and moist, and because of the venous congestion there is a cyanosis of the lips and tongue. The heart sounds are weak, often irregular, and the pulse is weak or imperceptible.

The arterial pressure is lowered, even unobtainable, and the venous pressure is raised as evidenced by prominent, strutted veins, particularly those of the neck. By direct measurement, this pressure is frequently above 200 Mm. of water, and a rise to 300 Mm. of water is not unusual. Such a pressure is consistent with life if not maintained for too long a period. Venous pressure readings should be obtained by the direct method of inserting a needle into a basilic vein and noting on an attached manometer the height at which a column of physiologic salt solution is maintained. The patient's body should be horizontal, and the vein should be on a level with the heart.

Roentgenograms are of no value, since death may occur from an amount of blood in the pericardial sac too small to cause a noticeable change in the size and contour of the heart shadow. Fluoroscopic examination, as shown by Bigger[19] is of great value, since the normal pulsations are prevented by a small accumulation of blood in the pericardial sac. Of all the diagnostic aids, this is the most accurate in proving or disproving one's suspicions of cardiac tamponade. It had best be undertaken with the portable fluoroscope, for with this unit the patient need only be turned on his side for examination.

To summarize:

(1) There is usually a history of freedom from symptoms for several minutes after the wound has been received, followed by rapid collapse and unconsciousness.

(2) Heart sounds are weak, as is the pulse.

(3) The arterial pressure is lowered.

(4) The venous pressure is raised.

(5) Fluoroscopic examination shows a quiet heart.

Operation should be carried out as soon as the diagnosis is established. To hasten and facilitate this, all necessary instruments should be kept ready in a separate container. Since infection of the pericardium and pleura is a frequent complication, meticulous care in preparation and technic should not be sacrificed for speed and haste. While preparations are being made, sufficient morphine should be administered to insure rest and quiet. The head should be lowered and the body kept warm. Theoretically, intravenous infusions are of little value so long as tamponade is present, but where excessive hemorrhage has occurred, it is indicated. The administration of a 6 per cent solution of acacia may be life-saving, and autotransfusion of the blood removed during the operation should be citrated and administered when possible. Blood transfusion should be undertaken as soon as possible after the release of the tamponade. For this purpose the "blood bank" is an invaluable aid.

Anesthesia.—Inhalation anesthesia is preferable to local anesthesia for

several reasons. The pleura may have been opened by the wound, or may be accidentally opened during the operation, and nitrous oxide and oxygen under positive pressure is necessary for the inflation of the lung. The difficulties of heart suture require that the patient be quiet, but these patients are usually wildly excited or are apt to become so with release of the tamponade, and unless completely anesthetized their struggles may interfere with the operation at a most inopportune time.

Suture of the Heart.—The incision should be so planned as to give the best exposure with the least trauma. It must also be made with some consideration as to the position of the external wound. Although the pleura is usually injured when the heart is wounded, further tearing of this membrane should be avoided if possible, for it adds greatly to the shock of the patient. For that reason dissection of the pleura from the pericardium is best begun in the fourth or fifth left interspace because of its lateral reflection at that point. It is this reflection to the left which leaves the pericardium uncovered by pleura at that point and so facilitates an extrapleural approach to the pericardium. It is of importance to remember that the costomediastinal lines of pleural reflection vary greatly; thus, either the left or right pleura may cross the middle of the sternum (Fig. 1). In a composite study of anterior pleural margins, Vosnitch was able to outline a small triangle of safety where the pericardium was uncovered by pleura. This lies behind the sixth left costal cartilage and sixth interspace (Fig. 2).

Unless the skin wound is well to the right of the sternum, the approach to the heart should always be made on the left, and the incision should be so planned that it can be readily enlarged if the heart wound is not easily located. With these factors in mind, experience has shown that a long transverse incision extending well across the sternum gives the best exposure (Figs. 3 and 4). By this approach one or two ribs can be removed, and, if necessary, the adjacent costal cartilages cut and a portion of the sternum removed. The pectoralis major muscle is separated in the direction of its fibers and can easily be retracted from the surface of three ribs. Dissection should begin well out on the rib, which can be easily lifted from its periosteal bed and cut without injuring the pleura. By lifting the rib, the cartilage can then be removed with less danger of injury to the pleura than if the cartilaginous portion is removed first. The internal mammary vessels are ligated and cut, the triangularis muscle is divided, and the pleura is displaced outward by careful gauze and finger dissection.

A second incision, and one giving excellent exposure, consists of turning a musculocutaneous flap laterally and removing two or more costal cartilages and ribs (Fig. 5). It requires more time to open and close the chest wall and is more likely to induce shock.

The incision should be planned to secure the best exposure in the quickest time and with the least shock. The median sternotomy (Duval-Barasty) (Fig. 6) gives excellent exposure to all the heart and the great vessels, but splitting the sternum requires a great deal of time, as does the closure of

the wound, and is productive of shock. It is mentioned only to condemn it, since in cases of severe hemorrhage or increasing tamponade the patient would not likely survive such a procedure.

The intercostochondral thoracotomy (Spangaro) offers a rapid approach to the heart but not a particularly good exposure. It can be enlarged by cutting or removing the cartilages above and below the incision and by removing a portion of the sternum.

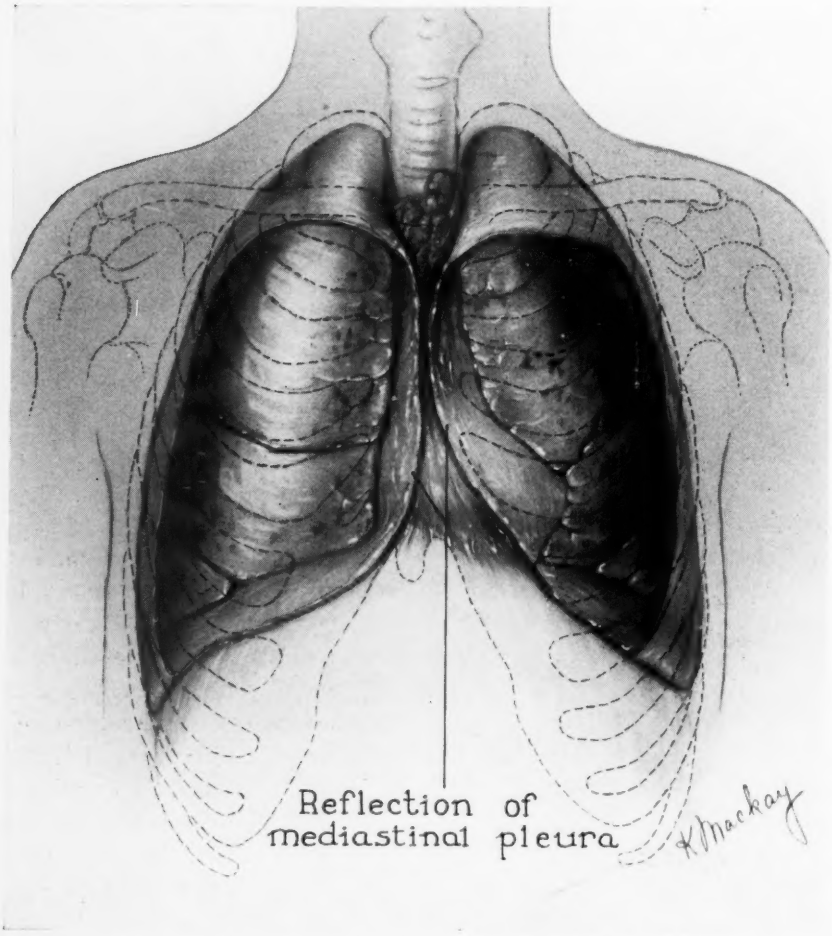

FIG. 1.—The usual anatomic relations in the anterior mediastinum.

The pericardium will be tense, bulging, and blue, and its pulsations will be weak and imperceptible. If the wound in the pericardium is seen, it should be enlarged, or, if not readily found, it is opened between stay-sutures of silk (Fig. 7). Occasionally, the heart wound can be located before the blood and clots are removed and before the heart starts bleeding profusely. If it is not immediately seen, the blood and clots are removed by suction. When the intrapericardial pressure is relieved, the bleeding becomes marked,

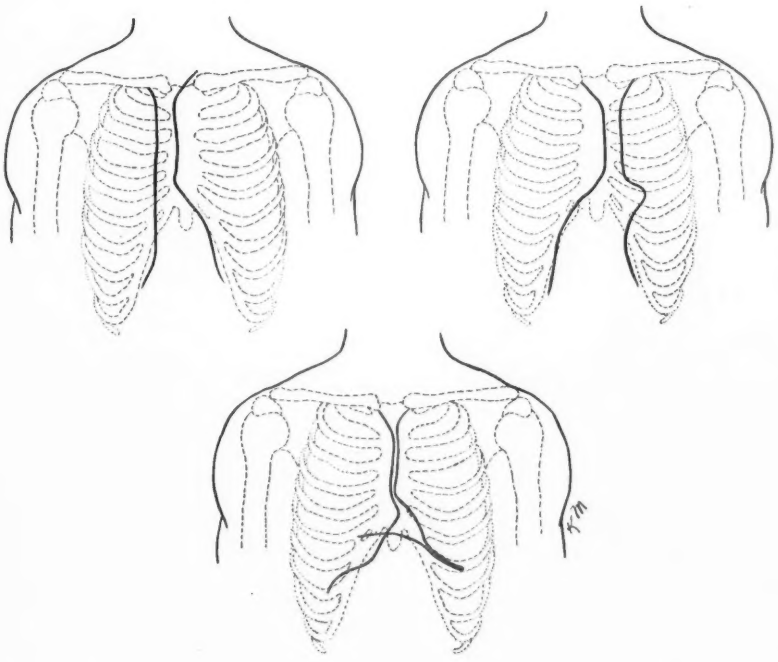

FIG. 2.—Diagrammatic representation of the lines of pleural reflection. Lower figure shows the triangle of safety (Matas).

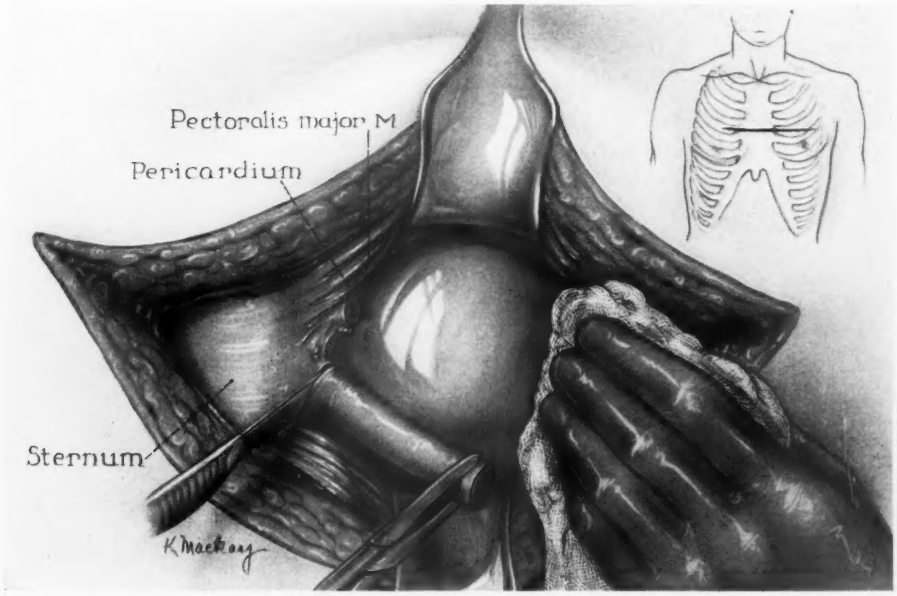

FIG. 3.—Showing the transverse incision, the removal of two ribs, and exposure of the pericardium.

as the contractions of the heart increase in force. When the wound is located, and it is most often found in the right ventricle, its closure is facilitated by placing the left index finger over it. In this way the bleeding will be impeded sufficiently to allow the passage of a suture directly under the finger. This is left untied for the moment and is held in the left hand for traction and hemostasis while other sutures are placed and tied. They should pass well into the substance of the muscle, but not into the chamber of the heart. Fine black silk on curved calix-eye needles is the material of choice. Heart muscle is extremely friable, and for this reason, the finger should not be placed *in* the wound, and sutures should be tied with only enough tension to approximate the edges (Fig. 8).

FIG. 4.—Patient showing a healed transverse incision.

Should the wound be behind the sternum or on the posterior surface of the heart, a stay-suture passed through the apex, as advocated by Ballance and by Beck, may be of great value, for by this means the heart may be rotated into such a position that the wound may be more easily sutured (Fig. 9).

Wounds in Special Positions.—Wounds of the auricle bleed with great rapidity and are more difficult to close because of the thinness and friability of the musculature in this location. Occasionally, a clamp, such as that used by Trendelenburg in closing the pulmonary artery, may be applied directly over the wound and the hemorrhage controlled until sutures can be taken (Fig. 10). If possible, sutures should not be carried into the chamber of the auricle because of the danger of an intra-auricular clot. Intrapericardial wounds of the great vessels will produce the same symptoms of tamponade as wounds in the heart muscle itself. They, too, are difficult to close because of the thinness of the structures. If the wound is in the pulmonary artery or aorta, the hemorrhage may be checked by passing the Trendelenburg probe behind them and thus impeding the flow of blood until the sutures can be placed (Fig. 10). Injuries to the coronary vessels may require ligature but are not necessarily fatal. I have found it necessary to ligate a major coronary vessel in three instances. All three of these patients survived, showing that this is not necessarily fatal. Electrocardiographic tracings in these patients show the typical findings of myocardial infarction. Where bleeding is so profuse that the wound cannot be located, it is sometimes necessary to resort to the procedure of Sauerbruch. In this, the venae cavae

are grasped between the middle and ring fingers of the left hand, and the first finger and thumb are left free to compress the cardiac muscle (Figs. 11 and 12). Needless to say, such a compression can be carried out for only a few minutes. During the course of any cardiac operation the heart may fibrillate or even stop beating, especially when traction is applied, or direct compression or kinking of the great vessels is employed. Should this occur,

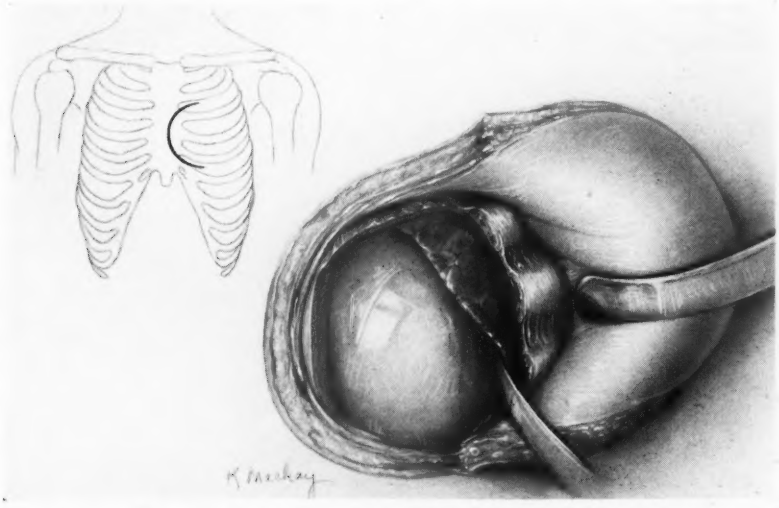

FIG. 5.—The approach to the pericardium through the musculocutaneous flap.

the operation should be momentarily stopped until normal contractions are resumed. The injection of one cubic centimeter of 1:1,000 solution of adrenalin directly into the heart muscle is frequently of value in restoring contractions. Gentle massage by pressure between the index finger and thumb will likewise often restore the heart beat.

After suture and control of the hemorrhage, the pericardial cavity is cleansed by suction and flushing with salt solution. The pericardium is loosely closed with interrupted sutures of silk, leaving sufficient space between the sutures for the escape of any fluid which may accumulate. Occasionally, the heart dilates to such an extent that complete closure of the pericardium is impossible. The muscle, fascia, and skin are then closed without drainage.

After operation the patient should be placed in an oxygen tent. Fowler's position will usually facilitate breathing. Morphine should be administered in sufficient amounts to insure rest and quiet.

Since the pleura and lung are often injured at the time of the heart injury, hemopneumothorax is frequently present. If its extent is such as to cause embarrassment of respiration, aspiration of the chest should be done, but in the absence of symptoms it is better to allow absorption of the air and blood.

Prognosis.—Immediate prognosis depends largely on the interval between

the injury and the operation. Delay may cause death from hemorrhage or tamponade or both. It likewise depends upon the character and extent of the injury; a bullet usually causes two wounds, with greater hemorrhage and tissue loss, and is rapidly fatal. Postoperative prognosis is largely dependent upon infection. Purulent pericarditis is apt to follow these wounds, which are necessarily contaminated and which may carry with them bits of clothing or other foreign material. Pneumonia resulting from lung injury, or as a part of the generalized infection, may likewise follow.

Thirty-eight patients with heart wounds have been operated upon by me or my Resident Staff (Fig. 13). Of these, 22 recovered and none of them have any residual symptoms referable to the injury. All wounds were pro-

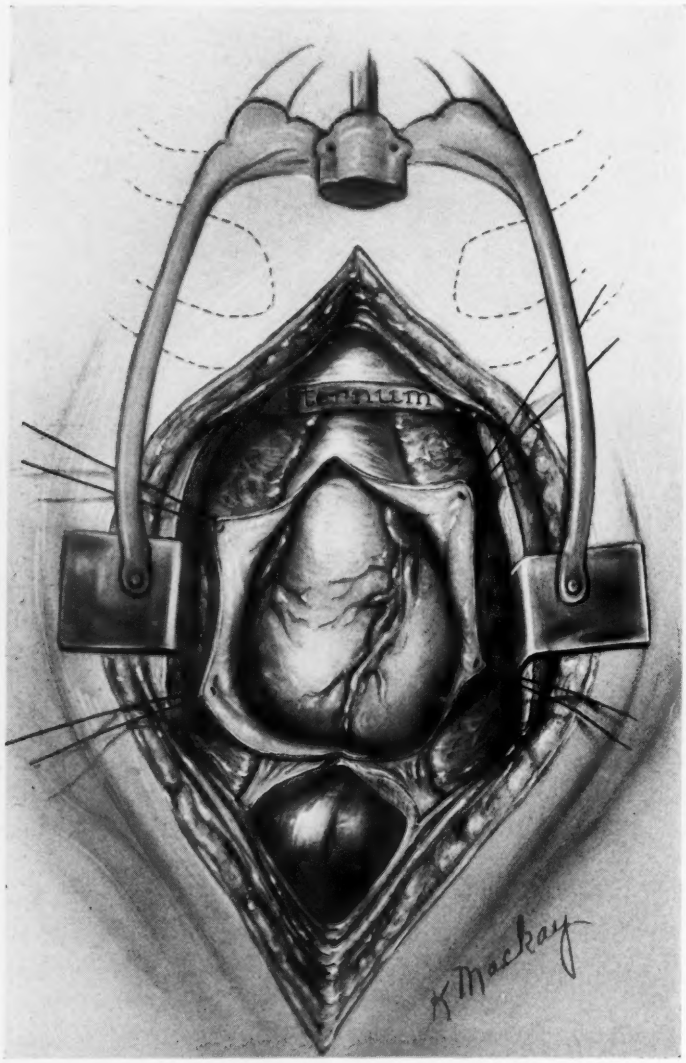

FIG. 6.—The Duval-Barasty median sternotomy (after Cutler).

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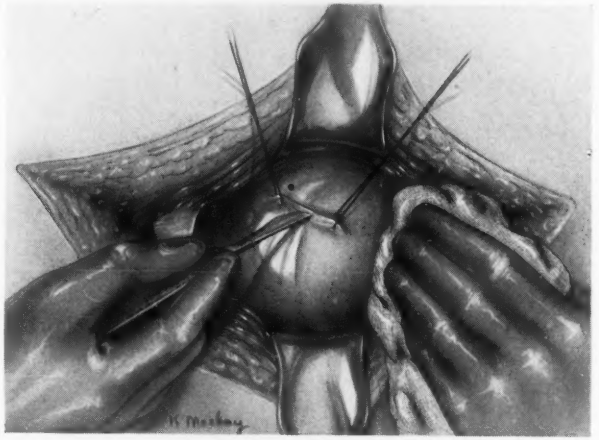


FIG. 7.—The opening of the pericardium between stay-sutures.

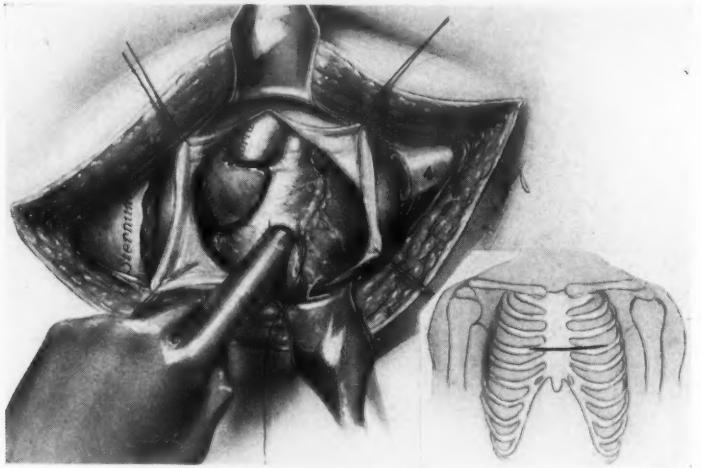


FIG. 8.—Method of controlling hemorrhage while suture is passed under finger.

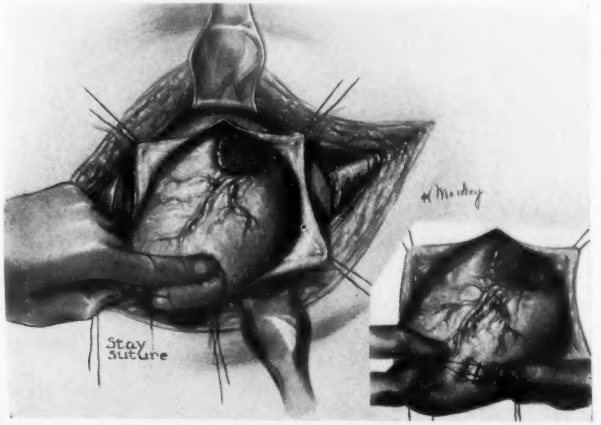


FIG. 9.—The use of the stay-suture in rotating the heart into position for suture (after Beck).

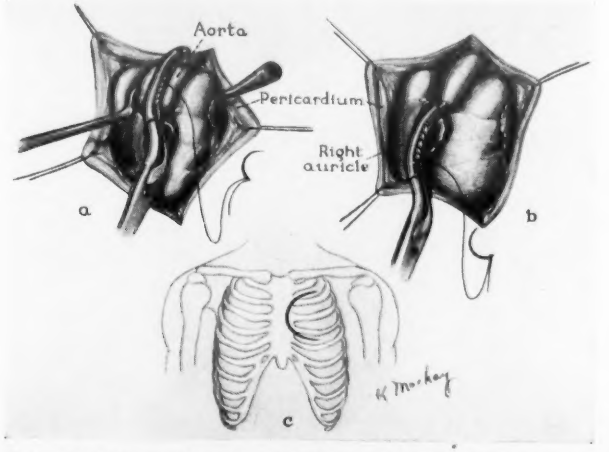


FIG. 10.—The use of the Trendelenberg probe and clamp in arresting hemorrhage in the auricles and great vessels.

FIG. 11.

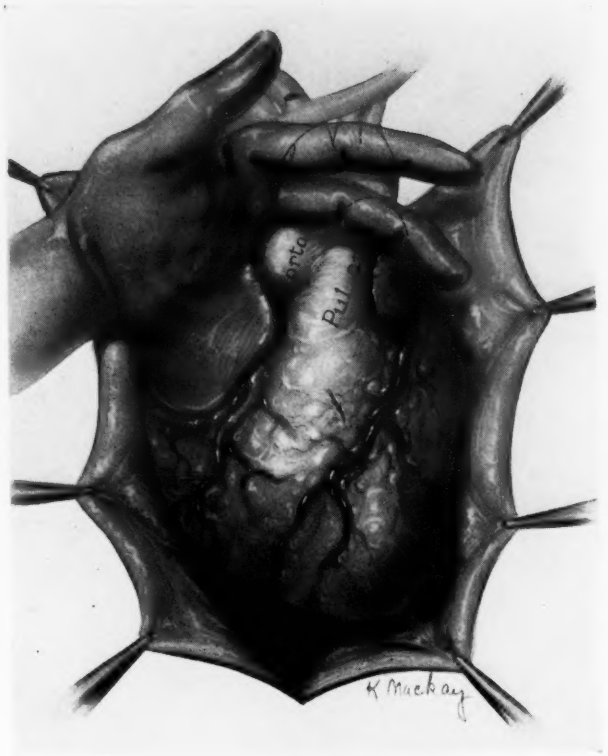
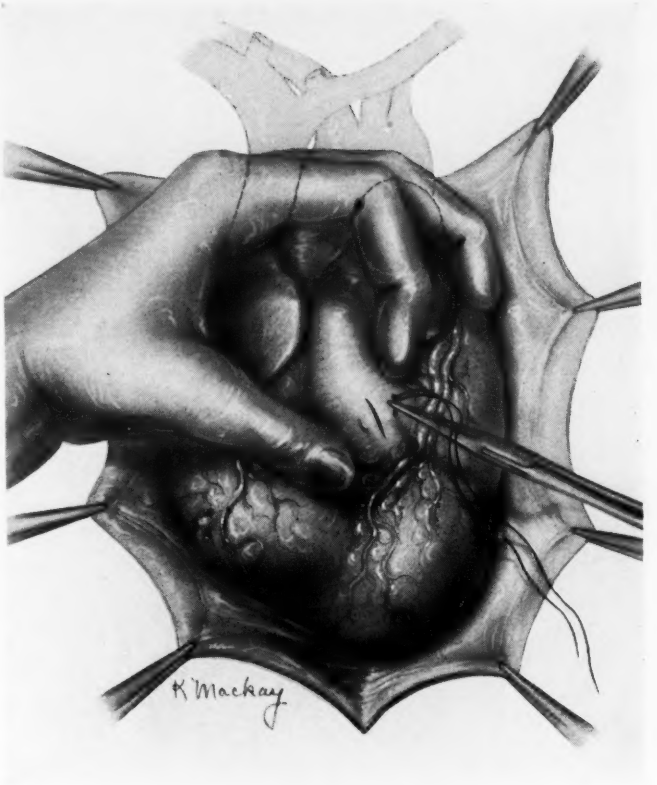


FIG. 12.



FIGS. 11 and 12.—"The Sauerbruch grip" illustrating the method of controlling hemorrhage by compression of the great vessels.

duced by knife or ice-pick except one (Case 37), which was caused by a bullet. In no instance was operation not undertaken because of the patient's condition. This means that in several instances the condition of the patient was so serious that there was practically no hope for recovery. No patients were operated upon in which the diagnosis was found to be incorrect, but

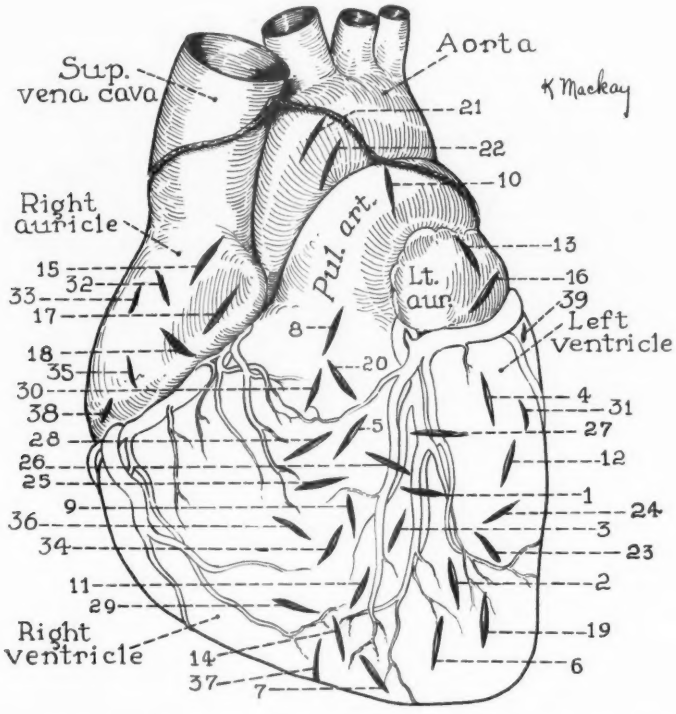


FIG. 13.—Composite picture showing the approximate location of the heart wounds reported in this paper.

it is only fair to say that some patients may have died with cardiac wounds upon whom operation was not performed. In two patients operated upon death occurred because of unnecessarily delayed operation, the result of failure of early diagnosis. There was one death from a postoperative hemorrhage due to the failure to ligate properly the internal mammary artery. The mortality rate in this series of 38 cases has gradually decreased, due, I believe, to the alertness of a Resident House Staff in establishing the diagnosis early and to better teamwork both at the operation and in post-operative care. The position of the right ventricle, occupying the greater part of the anterior portion of the heart, accounts for the fact that 14 of the 38 injuries were in that chamber. That ten of these patients survived is probably due to the fact that the right ventricle is easier to approach and suture. While pericardial adhesions undoubtedly form after these injuries, they are not of such a character as to produce symptoms either by constric-

tion or by increasing the work of the heart. That an already damaged heart can undergo considerable operative interference has been shown in those patients operated upon for coronary occlusion and for cardiac constriction. One of the patients in this series had been treated previously for myocardial failure. He recovered following the suture of a wound of his heart and is alive two years after the operation (see Tables I, II, and III).

Cardiac Rupture and Contusion.—Another type of cardiac injury which undoubtedly occurs with greater frequency than is generally supposed results from crushing wounds, usually from automobile accidents. Many are immediately fatal and are due to rupture of the heart, lungs, or great vessels as a result of compression of the thoracic viscera or penetration of the heart by broken ribs or sternum. Bright and Beck[21] collected 176 instances of injury to the heart following penetrating wounds of the chest, and have called attention to this type of injury as a common, though frequently overlooked, cause of death.

Certainly, there is no reason to believe that the heart, situated as it is between the sternum and the spine, is not subject to contusions of considerable severity; nor is there any reason to believe that recovery does not take place in the majority of instances. Other organs, notably the kidneys, are frequently the recipient of contusions from which they completely recover. The most common cause of such an injury is an automobile accident, in which an individual is suddenly thrown forward against the steering wheel. The sternum and ribs may be broken, and their ends directly injure the heart, or the sudden compression of the heart may injure it, although a break has not occurred (Fig. 14).

One can only speculate as to the exact nature of these injuries or as to the manner in which they are produced. In those patients who survive there is probably a contusion of the heart muscle with some hemorrhage into the myocardium, or gross hemorrhage into the pericardium.

Little attention has been paid to nonpenetrating heart lesions which are not fatal. Any patient who is struck in the chest must be suspected of such an injury, particularly if such symptoms as precordial pain, dyspnea, and tachycardia are present. Persistence of these symptoms, together with irregularity of the heart, cyanosis, and a peculiar "tick-tick" quality of the heart sounds, makes the diagnosis almost certain.

Cases of this kind give rise to speculation as to the eventual outcome, and raise many difficult medicolegal questions. Cardiac neuroses and malingering must always be considered, especially where the predominating symptoms develop following an injury to the chest in a patient previously well, it must be assumed that the symptoms are the result of that injury.

The treatment is entirely symptomatic. The chief reliance is to be placed on morphine and sedatives for quiet and rest, and on oxygen for dyspnea and cyanosis. Digitalis may be given but is of doubtful value. Above all, a patient with even a suspected cardiac lesion should be confined to bed until all symptoms have subsided.

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TABLE I

SUMMARY OF 38 CASES OF CARDIAC WOUNDS

Case No.	Sex	Age	Instrument	Period from Duration to Admission	Location	Result	Cause of Death	Survival Period	Comment
1	M.	18	Knife	30 minutes	R. ventricle and coronary	Recovery	.....	.....	Well 8 years
2	M.	25	Knife	40 minutes	L. ventricle	Recovery	.....	.....	Well 9 years
3	M.	41	Knife	30 minutes	R. ventricle	Death	Pericarditis	3 days	Necropsy; wound healed
4	F.	25	Knife	"Few min."	L. ventricle	Death	Hemorrhage	None	Large wound; died on table
5	M.	30	Knife	?	R. ventricle	Recovery	.....	.....	Well 4 years
6	M.	30	Knife	"Few min."	L. ventricle	Death	Pneumonia	2 days	Necropsy; wound healed
7	M.	21	Knife	30 minutes	R. ventricle	Recovery	.....	.....	Well 3 years
8	M.	32	Knife	Not known	R. ventricle	Death	Emphysema	14 days	Mediastinal emphysema
9	F.	27	Knife	60 minutes	R. ventricle	Recovery	.....	.....	Well 3 years
10	M.	24	Ice-pick	Not known	Pul. artery	Death	Pneumonia	2 days	Necropsy not done
11	M.	34	Knife	Not known	R. ventricle?	Recovery	.....	.....	Well 5 years
12	M.	22	Ice-pick	Not known	L. ventricle	Death	Bacteremia	36 hours	Necropsy; wound healed
13	F.	36	Ice-pick	"Few min."	L. auricle	Recovery	.....	.....	Well 2 years
14	F.	30	Ice-pick	"Few min."	R. ventricle	Recovery	.....	.....	Well 2 years
15	M.	20	Knife	15 minutes	R. auricle	Recovery	.....	.....	Well 15 months
16	M.	43	Knife	Not known	L. auricle	Death	Hemorrhage	None	Died from hemorrhage at operation
17	M.	36	Knife	30 minutes	R. auricle	Death	Infection	3 days	Necropsy not done
18	M.	22	Knife	1 hour ?	R. auricle	Death	Hemorrhage	None	Died from hemorrhage at operation
19	M.	30	Ice-pick	Not known	L. ventricle	Death	Pneumonia	2 days	Necropsy; wound healed; pneumonia
20	M.	30	Knife	Not known	R. ventricle	Recovery	.....	.....	Well 11 months
21	F.	28	Ice-pick	"Few min."	Aorta	Recovery	.....	.....	Well 2 years
22	M.	..	Ice-pick	Not known	Aorta	Death	Pneumonia	2 days	Necropsy not done
23	M.	38	Ice-pick	Not known	L. ventricle	Recovery	.....	.....	Well 2 years
24	F.	..	Knife	1 hr. 20 min.	L. ventricle	Death	Tamponade	None	Died during operation
25	F.	19	Knife	1 hr. 30 min.	R. ventricle	Death	Hemorrhage	5 hours	Did not react
26	M.	29	Knife	Not known	R. ventricle and coronary	Recovery	.....	.....	Well 16 months
27	M.	24	Knife	Not known	R. ventricle and coronary	Recovery	.....	.....	Well 16 months
28	M.	..	Knife	30 minutes	R. ventricle	Death	Hemorrhage	None	Died on table
29	M.	39	Knife	Not known	R. ventricle	Recovery	.....	.....	Well 15 months
30	M.	40	Knife	30 minutes	R. ventricle	Recovery	.....	.....	Well 10 months
31	M.	39	Ice-pick	Not known	L. ventricle	Recovery	.....	.....	Well 11 months
32	M.	28	Knife	Not known	R. auricle	Recovery	.....	.....	Well 11 months
33	M.	35	Knife	Not known	R. auricle	Recovery	.....	.....	Well 10 months
34	M.	24	Knife	30 minutes	R. and L. auricle	Death	Hemorrhage	24 hours	Secondary hemorrhage; int. mammary artery
35	F.	38	Knife	Not known	R. auricle	Recovery	.....	.....	Well 3 months
36	M.	21	Knife	1 hr. 50 min.	R. ventricle	Death	Tamponade	2 hours	Respiratory death
37	M.	24	Pistol	50 minutes	R. ventricle	Recovery	.....	.....	Well 2 months
38	F.	19	Ice-pick	1 hour	L. auricle	Recovery	.....	.....	Well 3 months

TABLE II

CAUSE OF DEATH

	No. of Cases
Hemorrhage	6
Pericarditis, infection	3
Pneumonia	4
Emphysema	1
Tamponade	2
Total	16

TABLE III

LOCATION OF WOUND

	No. of Cases	Pat's. Recov.
Aorta (intrapericardial)	2	1
Pulmonary artery (intrapericardial)	1	0
Right auricle	6	4
Left auricle	3	2
Right and left auricle	1	0
Right ventricle	14	10
Left ventricle	8	3
Right ventricle and coronary	3	2
Totals	38	22

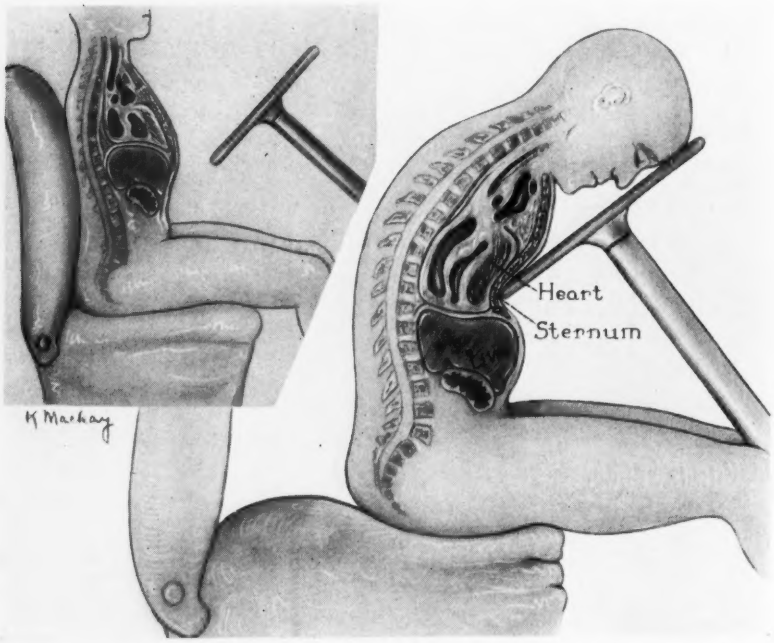

FIG. 14.—Diagrammatic representation of cardiac injury by the impact of a steering wheel.

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AN EFFECTIVE METHOD FOR THE DEVELOPMENT OF COLLATERAL CIRCULATION TO THE MYOCARDIUM*

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A method for the development of collateral circulation to the dog heart was described previously by Heinbecker and Barton[1] (1940). Microscopic studies and perfusion experiments demonstrated that by it an apparently satisfactory collateral circultion could be established. The present communication presents evidence that the collateral circulation so produced, can prevent the fatal ventricular fibrillation as well as the gross myocardial infarction which are so frequently encountered after the occlusion of large branches of the coronary arteries.

The problem of securing a functional test of the efficacy of collateral circulation to the heart is a difficult one. Burchell[2] (1940) recently, and others, previously, have summarized the results of ligation of the main branches of the coronary arteries in animals by various operators. The results have been highly variable both as regards survival rate and the degree of myocardial infarction. Any attempt to measure the value of a collateral circulation by determining the mortality rate after ligation of any of the major coronary branches would require the use of a large number of animals, in order to allow a statistical comparison of the results with the better results reported by previous operators. Fortunately for our purpose, no one has found it possible to achieve survival in the normal dog following complete ligation, at one sitting, of both branches of the left coronary artery near their points of origin. It was decided, therefore, to apply this test to the collateral circulation established by our method. It follows that any survivals from such a test would owe their existence to the beneficial effects of the established collateral circulation.

Present Method for Producing Collateral Circulation to the Myocardium.—Our present method for producing the collateral circulation to the heart involves the introduction into the pericardium of an irritating mixture which causes an adhesve pericarditis. At the same operation, the pericardium is attached by sutures to the retrosternal tissues. The procedure differs slightly from that which we have previously described, in that a mixture previously prepared is used as an irritant instead of a number of separate ingredients. This mixture can be inserted into the pericardial sac through a relatively small

* Presented by title before the American Surgical Association, White Sulphur Springs, W. Va., April 28, 29, 30, 1941.

MIXTURE TO PRODUCE PERICARDIAL ADHESIONS

Commercial gelatin	32.5 Gm.
Aleuronat	32.5 Gm.
Starch	50.0 Gm.
Glycerin	275.0 Cc.
Water	200.0 Cc.

Put gelatin, aleuronat, starch, and glycerin into a container. Add boiling water and stir over bath 30 minutes. When the paste is smooth, add 32.5 Gm. lionite No. 60 and stir until thoroughly mixed. The mixture is semisolid at room temperature, semiliquid at 38° C.

hole by a grease-gun with a long curved nozzle which can be directed to all parts of the enclosed cavity. After the material is introduced, the pericardium is closed and sewed to the retrosternal tissues by four interrupted silk sutures.

Experiments to Test the Efficacy of the Collateral Circulation.—Fourteen animals were prepared in the above manner. Four to 12 weeks after the first operation, the animals were again operated upon and silk ligatures were applied to the anterior descending and to the left circumflex arteries about one centimeter from the aorta. Eight of the 14 animals died in a few minutes, death always occurring after the second of the two arteries was ligated. The remaining six animals, however, tolerated this operation well and they lived in apparent good health for one to three months (Table I). At the end of

TABLE I

Dog No.	Date of Establishment of Collateral Circulation	Date of Coronary Artery Ligation	Date of Autopsy	Findings
				Left anterior descending and left circumflex arteries and accompanying veins ligated
B2	3/13/39	6/ 5/40	7/24/40	No gross infarction of myocardium
84	12/22/39	3/13/40	6/ 5/40	No gross infarction of myocardium
77	12/18/39	6/ 5/40	7/24/40	No gross infarction of myocardium
72	12/12/39	6/ 5/40	7/24/40	No gross infarction of myocardium
65	12/ 1/39	6/ 5/40	7/24/40	No gross infarction of myocardium
46	4/24/39	9/23/39	1/ 4/40	No gross infarction of myocardium

this period, they were sacrificed to obtain proof of the adequacy of the ligations. Autopsy revealed that the arteries and their accompanying veins had been completely ligated in all six animals. Examination of the heart musculature showed an absence of gross infarction. Microscopic sections revealed a well-developed pericarditis and heart musculature which appeared normal except for scarring in the immediate vicinity of the ligatures (Fig. 1).

The anterior descending and left circumflex branches of the left coronary artery of 14 control animals were ligated in the same manner. In all instances death, due to ventricular fibrillation, occurred within three to five minutes. In 50 per cent of the cases, fibrillation developed after the ligation of only one artery.

Relative Importance of Extrinsic and Intrinsic Collaterals.—In 11 dogs, the mixture was inserted into the pericardial cavity and then a large sheet of

cellophane was placed between the pericardium and the retrosternal tissues. It was held in position by a few interrupted silk sutures. In none of these animals were adhesions found, subsequently, between the pericardium and retrosternal tissues. After a period of one to three months, nine of the

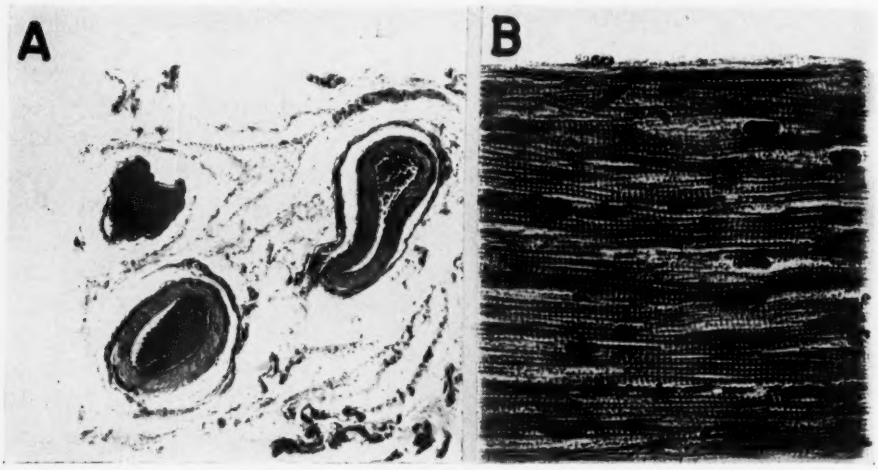

FIG. 1.—(A) Photomicrograph of pericardium over anterior surface of the left ventricle of Dog No. P77, after establishment of adhesive pericarditis and attachment of pericardium to retrosternal tissues. Note large blood vessels. Survival after ligation of both branches of the left coronary artery near their origin. (×38)

(B) Photomicrograph of heart muscle of left ventricle of Dog No. P72, 2 cm. distal to the points of ligation of anterior descending and circumflex branches of left coronary artery near their origin, with survival. Note its normal structure. (×390)

animals were operated upon again, and an attempt made to ligate the anterior descending and left circumflex branches of the left coronary artery one centimeter from their points of origin. All the animals died promptly from ventricular fibrillation, often after ligating only one of the arteries. The remaining two animals were sacrificed without ligation of coronary arteries and the collateral circulation injected with India ink in the manner previously described (Heinbecker and Barton, 1940, *loc. cit.*[1]). In both of these animals many capillaries, filled with ink, were visible in the pericardial adhesions, but the inky fluid did not fill the cavity of the ventricles, as is customary in animals where the pericardium also has been attached to the retrosternal tissues. This is regarded as evidence that the degree of collateral circulation is much less in such animals than in those in which adhesions with retrosternal tissues are also present.

DISCUSSION.—It is thus possible to produce a collateral circulation to the myocardium of the dog, which is adequate to prevent the degree of ischemia which invariably results in ventricular fibrillation and death when the two main left coronary branches are ligated. Such collateral circulation is also adequate to prevent gross myocardial infarction. By the method employed, additional intercoronary collaterals developed by the pericarditis are not sufficient in themselves to prevent death from such extensive myocardial ischemia. To produce a really effective collateral circulation to the heart, there must be

an extrinsic source, and this should contain large-sized blood vessels in which a high arterial pressure exists. It would also seem to us an additional advantage to have such an extrinsic source remain in its normal environment.

Under our experimental conditions, the insult to the myocardial circulation of the animals was great. It is probable that the degree of myocardial ischemia which can produce pain in many may be much less. It might, therefore, be prevented by much lesser degrees of collateral circulation such as could be afforded by the additional intercoronary capillaries produced by the pericarditis itself. For protection against greater degrees of sudden myocardial ischemia, an extrinsic source of collateral circulation would, doubtlessly, also be required. Only through clinical experience can we obtain actual knowledge concerning the degree of collateral circulation which is necessary to prevent pain and ventricular fibrillation which leads to death from coronary disease in man.

In any attempt to apply the procedure to man, certain problems will at once arise. First, would be the question of the safety of the mixture needed to produce the pericarditis. Apparently, the substance used in the animals can be used in man. In one patient, a mixture of aleuronat, lionite, and sodium morrhuate produced no disturbance of the cardiac rhythm after 15 cc. of a 10 per cent procaine solution had been previously placed into the pericardial cavity and allowed to remain for five minutes. This preliminary application of procaine has been advocated by Mautz[3] (1936) as a means of diminishing the irritability of the heart muscle, and thereby tending to inhibit the development of ventricular fibrillation. In the same case, no appreciable degree of pericardial effusion resulted from the use of 60 cc. of the material. The possibility that a pericardial effusion might develop and lead to cardiac tamponade cannot be entirely ruled out, and perhaps should be guarded against by incomplete closure of the pericardial sac. Any leak of material would serve to increase the adhesions between the pericardial sac and surrounding structures, which could only be beneficial. In over 100 animals, in which pericarditis has been produced by the mixture, death from cardiac tamponade resulted only twice. No effort was made to diagnose or treat the condition before autopsy in these two instances.

In the dog, the mobility of the mediastinum is such that the pericardium is readily elevated to the retrosternal tissues. In man, such an elevation will be possible only in cases where there is not much enlargement of the heart. With large, heavy hearts a limited anterior thoracoplasty might be necessary to permit approximation of the pericardium and retrosternal tissues. Experiments are now in progess to determine whether or not an island of retrosternal tissue, with the internal mammary arteries running to it, can be successfully displaced and grafted to the pericardium.

SUMMARY AND CONCLUSIONS

An effective method of producing a collateral circulation for the dog's myocardium is described.

The effectiveness is proved by the fact that following complete ligation, at one operation, of the anterior descending and left circumflex branches of the left coronary artery approximately one centimeter from the aorta, six out of 14 dogs survived. In control animals, such ligations were invariably immediately fatal.

At autopsy, the heart muscle of the surviving animals showed no gross infarction.

On the basis of the experimental evidence, it is felt that, for a maximally effective collateral circulation to the heart, the extrinsic source should contain blood vessels of large caliber.

The method should be appliable to the treatment of myocardial ischemia in man.

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THE TREATMENT OF VASCULAR INJURIES *

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A REVIEW of the surgical treatment of vascular injuries seems particularly in order at the present time, since we are confronted with the possibility of entering upon another war.

It is a far cry from the bow and arrow wounds of early Indian wars, through the musketry, rifle, and cannon-shot injuries of the Revolutionary, Mexican, and Civil wars, the steel-jacketed bullet wounds of the Boer and Spanish-American wars, the high explosives and gas injuries of the World War, to the wounds of mechanized and airplane warfare of the present conflict.

Though the nature of wounds in wars of varying periods has differed greatly, all serious wounds have been characterized by three outstanding features, namely, pain, shock, and loss of blood. To this unfortunate combination is due most of the morbidity and mortality of the casualties of combat.

Transfusion.—The most striking advance in the surgical treatment of the wounded has been directed toward the relief of shock and hemorrhage, and has been brought about by improvements in transfusion service.

From his book on Transfusion, published in 1922, by Dr. Geoffrey Keynes, an honorary member of this Association, I quote the following: "During the first two years of the World War almost nothing was known in the British Army of its possibilities. I have no evidence that the French or German Army doctors were any better informed than ourselves. Some attempt was made, in 1916, to introduce the use of direct transfusion through cannulae, but the technic was too difficult and uncertain for the stress of war conditions. It was not until 1917, when the British Army Medical Corps was being steadily reinforced with officers from the United States of America, that knowledge of blood transfusion began to be spread through the armies."[1]

Again, concerning the vagueness of indications for transfusion, from the work on Gunshot Injuries of the Blood Vessels by Major General George H. Makins, Senior Consulting Surgeon to the British Expeditionary Forces in France, published in 1919, I quote the following: "With a moderate hemorrhage there is no need to replace the lost blood artificially. If the bleeding has been severe, the loss can be made good by a more easily obtainable fluid, *i.e.*, 6 per cent gum arabic solution. A precise indication as to when blood transfusion is imperative is still wanting and much to be desired. Most observers agree that a critical point has been reached when the total hemoglobin content is as low as 30 per cent."[2]

These comments on transfusion in the British Army in the World War

* Read before the American Surgical Association, White Sulphur Springs, W. Va., April 28, 29, 30, 1941.

are in striking contrast to the situation which exists in England to-day. Doctor Philip Wilson, who has recently returned to this country after having established an American Orthopedic Service in London, has given an interesting account of the operation of transfusion service in the London hospitals, from which I have made the following brief extract:

"All these hospitals are regularly supplied with citrated blood, plasma, and dried serum from one of the four blood depots organized by a committee of the Medical Research Council." At the hospital with which his group was associated, and this is the routine with others, he says: "The supply truck called regularly every Monday and delivered 12 half liters of blood and took away the unused remainder of the blood that has been left from the previous week to be converted into plasma. The blood supply service also replenished the stock of plasma and dried serum and kept it up to an agreed level."[3]

This service can be duplicated wherever there is need. In the Spanish Civil War, similar blood transfusion centers were established and transfusions were extensively used. It is estimated that 10 per cent of the wounded could be saved through this agency.

It is safe, therefore, to claim that the soldier who has the misfortune to be seriously wounded at the present time, has less to fear from shock and hemorrhage, by reason of the availability of transfusion, than at any time in any previous conflict.

Classification in Regard to Indication for Treatment.—In considering the indication for treatment, vascular injuries fall into three general classifications:

(1) Those which demand immediate repair.
(2) Those in which delay, at least for a brief period, is permissible.
(3) Those which, for various reasons, come under observation at a late period. These will consist mainly of traumatic aneurysms and arteriovenous communications.

Hans von Haberer has made valuable contributions to the literature of vascular injuries, founded on his experience on the German side in the World War. He summarizes the rules to be followed in advanced front line units in dealing with injuries to the extremities as follows:

(1) Amputation should be carried out when there is no chance to preserve the limb or its functional value.
(2) Ligation of bleeding vessels in the wound or at the site of choice should be practiced when restoration of the limb can be expected.
(3) When hemorrhage is not threatening, it may be controlled by a compression bandage. If an Esmarch's bandage is employed, it should not be left in place longer than from one to three hours.
(4) In smooth gunshot wounds without laceration of the soft parts, when the hemorrhage stops soon, the artery should not be searched for but the wound should be left alone so that an aneurysm may be formed.

Continuing further, he says: "Following the injury of a main artery, in the absence of extensive laceration of the soft parts, the external hemorrhage may stop rapidly and spontaneously, due to the fact that the various layers have different degrees of elasticity, and, by their displacement, obstruct the path of the hemorrhage. Consequently, an hematoma forms in the soft parts and reduces further hemorrhage by compression of the bleeding artery. A pulsating hematoma will be produced, and it represents the precursor of a false aneurysm. The development of an aneurysm of this type should be one's aim, since its surgical treatment, carried out at least 12 days after injury and preferably during the third or fourth week, has proved very successful."[4] Venous bleeding can usually be controlled by a compression bandage.

Delayed Operations.—Those who have survived the immediate effects of vascular injury and who are, in a measure, convalescent, may be evacuated to base hospitals where the facilities for observation and treatment are similar to those provided in well-organized civilian hospitals.

As previously noted, von Haberer advises that traumatic aneurysms be not operated upon until the twelfth day, and, preferably, during the third or fourth week. The British and French were inclined to a longer delay. Makins prefers a delay of two or three months and Matas holds the same opinion. Mont Reid[5] believes that arteriovenous fistulae should not be operated upon for six months after injury, and offers the following reasons in support of his opinion:

"In some cases, hemorrhage, increasing hematoma, infection, and, very rarely, acute cardiac symptoms make it necessary to operate soon after injury. When none of the foregoing complications make operation imperative, delay presents the following advantages:

(1) A good collateral circulation develops which permits excision of the fistula without fear of gangrene.
(2) The injured vessels become thoroughly healed, making their dissection easier and safer.
(3) Infection is less likely to occur.
(4) Spontaneous healing may take place."

Most of these advantages apply to aneurysms as well as to arteriovenous communications.

Dangers Inherent to Ligation of Arteries.—In wounds of major arteries, the question of ligation or repair, immediately or at a later date, will come up for consideration.

Leriche and Werquin[6] list the disturbances following ligation as:

(1) Mechanical syndrome; varying from massive gangrene down to localized necrosis in muscle causing orthopedic troubles later on.
(2) Functional disturbances, such as cyanosis, trophic disorders and muscular paralysis.

The ideal prophylaxis against these dangers is the substitution of suture

for ligature, which they consider generally impossible in war wounds, and which has limitations which we shall presently discuss.

It is obvious that ligation in the presence of exsanguination, with attendant low blood pressure, vastly increases the likelihood of massive gangrene, hence the necessity for adequate transfusion for replacement of lost blood and for restoring and maintaining blood pressure.

Since many ligations are imperative, it is important to consider recent experimental and clinical investigations which have developed methods for increasing their safety.

Measures for Increasing the Safety of Ligations.—Gage and Ochsner,[7] in a recent paper, suggest a number of measures which are necessary for successful arterial ligation. These have to do with the establishment and maintenance of efficient collateral circulation. They are classified under three heads: (1) Spontaneous, which occurs in arteriovenous aneurysms. (2) Mechanical, which may be accomplished by the Matas' compressor; intermittent venous occlusion, including the Paevex machine; and simultaneous ligation of the concomitant vein. (3) Physiologic, which results from chemical section of the cervicodorsal and lumbar sympathetics, by novocain or alcohol block.

They were so favorably impressed with the physiologic method of preventing ischemic gangrene in ten cases of ligation of major peripheral arteries, and in four cases of emboli in the femoral arteries, that they prefer it to all other measures.

Leriche and Werquin[6] have studied the effects of arterial ligation upon the vasomotor system. According to their observations "a ligature acts as a severe trauma and produces reflex vasoconstriction distally. This reflex is removed by resection of the obliterated length of the affected artery. The reflex can also be abolished by arterial section between ligatures; by periarterial sympathectomy above the lesion; by anesthetic infiltration of the adventitious coat; by regional infiltration of the sympathetic system; or by ganglionectomy."

They[6] advise limited resection of artery between ligatures; maintenance of blood pressure to help the rapid flow of blood back into the limb; periarterial sympathectomy above the lesion; or section of the regional sympathetic plexus.

"It is important to remember that if infiltration is to be undertaken, it must be done at once. Delay is fatal, because tissues die quickly." With the employment of these safeguards, they hold that "ischemic gangrene should no longer be inevitable, and the risk attending arterial ligature should be much lessened."

In keeping with what we have just quoted from Gage and Ochsner, Leriche[6] says: "Infiltration of the cervical or lumbar sympathetics is more necessary than warming the patient with cotton-wool or with radiant heat. It is not the skin that wants the warmth so much as the deep tissues."

Arterial Suture.—Arterial suture is the ideal method of preserving the

circulation in distal parts which ligation might jeopardize. Except under most favorable surroundings, in clean wounds, and, preferably, in those in which the tissues have completely healed, suture is prone to be followed by immediate thrombosis or delayed aneurysmal formation; hence, Leriche points out that suture is generally impossible in acute war wounds. In civil practice, operating under favorable surroundings, and usually in delayed cases, suture has proven very successful.

Very little has appeared, so far, in the literature concerning the treatment of traumatic aneurysms and arteriovenous communications in the present war. At a later and quieter period, this subject will, no doubt, receive the attention which its importance demands.

Bumm, a German surgeon, discusses "pulsating hematomata or spurious aneurysms as a sequel to war injury" and reports seven cases from the present conflict. He says: "Generally speaking, suture should be attempted when there is danger of untoward consequences from ligation. Suture is contraindicated in severe infection but may be used with a high degree of safety in the presence of light infection provided loose tamponade is applied for the purpose of drainage."[8]

From the English viewpoint, based on his World War experiences, Mitchiner[9] writes discouragingly of reparative vascular surgery: "Under war conditions, the results of reparative surgery on blood vessels are notoriously disappointing. In a certain number of repair operations which he performed, some two-thirds thrombosed at once, but not a limb was lost. The remaining third maintained circulation. Three years later several of these cases were seen again. All those whose vessels had thrombosed were well and at work, while of those whose circulation had endured, nearly all had aneurysms."

Hans von Haberer, whose experience is extensive and whose views are sound, gives the following advice:

"Suture of an artery should not be performed in cases in which the artery could be ligated without damage to the nutrition and function. This holds true for the external carotid and its branches, and for those peripheral arteries which supply their areas in pairs, such as the radial and ulnar and the anterior and posterior tibials. Suture is especially indicated in the internal and common carotids, the axillary, subclavian, and brachial, external and common iliacs and popliteal, and the femoral above the origin of the profunda."

He reports that he has operated upon 251 aneurysms, with 182 sutures, and 69 ligations, and considers the danger of thrombosis to be slight. There were 14 deaths—12 from septicemia from multiple injuries; two from shock and hemorrhage. Six deaths were in the suture group. There were three amputations and one recurrence of the aneurysm. In ligations he recommends the intrasaccular method of Kikuzi and von Frisch.[4] This does not differ in any respect from the endo-aneurysmorrhaphy of Matas, introduced in 1888, and practiced universally since that date.

Heparin.—The introduction of heparin gives promise of great therapeutic value in vascular surgery. Murray and his associates[10] have made interesting reports of their experimental and clinical experiences with its continuous intravenous use in arterial and venous suture, venous grafts, embolectomy, mesenteric thrombosis, pulmonary embolism and thrombophlebitis.

Whatever dangers may attend arterial suture in acute war wounds, those cases which are delayed, and which do not require early operation, may still be given the benefit of suture with much prospect of success.

Arteriovenous Aneurysms.—An entirely new conception of the pathology, as well as of the indications for operation in arteriovenous fistulae, has resulted from studies upon cases encountered in the World War and confirmed by clinical and experimental observations in civil practice.

The investigations of Gundermann, Caro, Makins, and Cazamian, carried on between 1915 and 1917, established the fact that arteriovenous fistulae between larger vessels results in definite and progressive heart damage. Reid, while working with Halsted, between 1914 and 1916, says: "In the course of two or three years, we became fully convinced that a fistula between the larger vessels of the neck or legs may cause marked hypertrophy and dilatation of the heart, and, in some instances, cardiac decompensation and death."[11]

This feature of an arteriovenous fistula is an added indication for operation, and, in many instances, the most compelling one.

Its importance was brought to the attention of the profession in 1923 by Matas,[2] in a paper entitled "The Systematic or Cardiovascular Effect of Arteriovenous Fistulae"; and again, in 1931, by Reid,[11] in a paper entitled "The Effects of Arteriovenous Aneurysms upon the Heart."

In uncomplicated cases, delay in operation for from four weeks (von Haberer) to six months (Reid) is desirable for reasons already set forth.

In cases of long standing, certain changes in the involved vessels, the collateral circulation, and the heart will usually have taken place. In the vein distal to the lesion, varicosities are frequent; in the artery proximal to the lesion, degeneration of the walls and dilatation of the lumen are often observed; in the heart, degenerative changes of varying degree are found. In all instances, an efficient collateral circulation is rapidly developed. Quadruple ligation and excision is indicated in these cases.

In early cases in healthy individuals, transvenous arterial suture is the method of choice in accessible fistulae. The ideal method would seem to be the separation of artery and vein with suture of the opening in both vessels, but Reid[13] points out that this measure has been followed by serious pulmonary complications, due to embolism of air and of blood clots from thrombosis at the site of operation. He considers that ligation of the vein is a safer procedure, and that it probably results in a better balance between arterial and venous beds, even though the artery is restored.

In cases of long standing, Matas,[12] and also Holman, advises that intermittent closure of the fistula by digital or mechanical pressure be practiced

for a time, in an attempt to prepare the heart for the shock of permanent closure of the fistula which it might not otherwise be able to withstand.

Early Cardiac Decompensation in Arteriovenous Aneurysms: Palliative Operation.—Few cases of early cardiac decompensation are on record. Mason, Graham and Bush report a traumatic arteriovenous aneurysm of the left subclavian vessels, not subjected to operation, that died on the fourth day from cardiac decompensation, as proved at autopsy. In this paper, four cases were abstracted from the literature, reported by Tixier and Arnulf, Rocher, Harvey Stone, and Caraven, in which serious cardiac disturbance or decompensation was noted by the fifth day in three instances, and by the fifteenth day in one instance.

As a temporary measure to relieve the embarrassed heart, Tixier and Arnulf suggest that the vein be ligated some distance proximal to the fistula, a curative operation to follow at a later date. The benefits of proximal ligation of the vein have been observed by Stone and by Holman, and Matas considers it a measure that should be helpful.[14]

Pulsating Exophthalmos.—Pulsating exophthalmos results from an internal carotid-cavernous sinus fistula. Approximately three-fourths of the cases are caused by trauma, and the remaining fourth by rupture of latent congenital or acquired aneurysms of the internal carotid or of arteriosclerotic patches on its wall. The treatment has been varied and the results uncertain.

Approaching the subject from the neurosurgical standpoint, Dandy has successfully treated two cases in which the internal carotid had previously been ligated in the neck without success, by occluding the intracranial portion of the artery by the application of a silver clip after it has emerged from the cavernous sinus and just before its division.

A perusal of Dandy's[15] paper, presented at the fifty-sixth meeting of the American Surgical Association, and of the discussion, which was taken part in by Doctors Matas, Naffziger, and Mont Reid, gives one a comprehensive review of the methods which have been employed in the treatment of this peculiar lesion.

Wounds of the Heart.—Writing from London, Mitchiner[9] says: "Under conditions pertaining in war—wounds of the heart, great vessels, and even the proximal ends of the limb—vessels are usually so rapidly fatal, either from primary hemorrhage or from gross damage to neighboring structures, that the patient seldom reaches the surgeon alive."

With present facilities for the treatment of shock and hemorrhage, together with airplane ambulance service and automobile-trailer operating units which the United States Army may install, we expect that some heart wounds will be successfully operated upon. In civil practice, successful cardiorrhaphies are being reported from every section of the country. The diagnosis of cardiac tamponade can be made with reasonable certainty, and in a brief period of time, by noting the location of the wound, the shock, low arterial blood pressure, and quiet heart. On reaching the hospital, the diagnosis can be confirmed by fluoroscopy of the heart, which will reveal the

absence of pulsations, and by finding a high venous pressure. The time element is of greatest importance, and if tamponade can be quickly relieved, the patient has an excellent chance for recovery when the wound has been sutured.

In the Hillman Hospital, during the past five years, 20 stab wounds of the heart have been operated upon by various members of the attending staff. The average time from infliction of injury to beginning of operation was one hour and 40 minutes. Six patients recovered and 14 died; six of these on the operating table. This recovery rate is by no means as good as is reported from other clinics, but it is worthy of record, since no case had been successfully operated upon in this institution previous to October, 1935.

Vascular Injuries in Civil Practice.—While, fortunately, in no way comparable to the great number of vascular traumata which occur in war, there is no lack of such clinical material in civil practice. To every large hospital which receives accident patients, sufferers from vascular wounds continually present themselves. It is a sad commentary on the present state of society that practically all these injuries result from personal altercations or conflicts with officers of the law.

Since 1932, a series of vascular injuries of major importance, 29 in number, have come under my care. They have presented the following conditions (Table I):

TABLE I

TYPES OF VASCULAR INJURIES SUSTAINED

Arteriovenous aneurysms	19
Traumatic aneurysms	4
Gunshot wounds of brachial artery	1
Cirsoids of scalp (traumatic)	2
Stab wounds of the heart	2
Extensive hematoma from rupture of femoral vein and branches	1
Total	29

TREATMENT AND RESULTS

	No.	*Recovered*	*Died*
Arteriovenous aneurysms (19)			
Quadruple ligation and excision	7	6	1*
Transvenous suture	2	2	
Lateral suture of artery, ligation of vein	2	2	
Recovered without operation	2	2	
Sudden death—fourth day. No operation	1		1
Refused operation	3		
Lost sight of while waiting for time for operation	2		
Aneurysms (4)			
Ligations—Common carotid	1	1	
Brachial	1	1	
Endoaneurysmorrhaphy—Femoral	1	1	
Lateral suture—Femoral	1	1	
Cirsoids of scalp—Multiple ligation and excision	2	2	
Gunshot wound of brachial—Ligation	1	1	
Laceration of femoral vein—Ligation	1	1	
Stab wounds of heart—Cardiorrhaphy	2		2

*One quadruple ligation and excision died from intercurrent disease after the wound had healed. One patient died six years after operation from cardiac decompensation due to a common carotid—left innominate fistula not found at original operation.

SUMMARY

The treatment of vascular injuries is discussed under the following headings:

(1) The great improvement in the treatment of shock and hemorrhage brought about by developments in transfusion since the World War.
(2) Classification of vascular injuries in regard to treatment:
  (a) Those which demand immediate treatment.
  (b) Those in which a brief period of delay is permissible.
  (c) Those which come under observation at a late period.
(3) Dangers inherent to ligation of arteries, especially in patients already exsanguinated.
(4) Measures for increasing the safety of ligations.
(5) Suture *versus* ligature.
(6) Traumatic aneurysms and arteriovenous communications.
(7) Wounds of the heart.
(8) Vascular injuries in the current war.
(9) Experience in civil practice.

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DISCUSSION.—DR. DANIEL C. ELKIN (Atlanta, Ga.): Doctor Mason has amply covered, in the short time allotted to him, his very important subject, and, therefore, I will only emphasize the points which he brought out.

In the first place, it must be remembered that an hematoma in itself may be injurious by cutting off lateral circulation, and sometimes it may be advantageous to remove the hematoma, even though ligation of a major vessel will then have to be carried out. Ligation of accompanying veins should certainly be done where a major artery is ligated, and temporary sympathectomy by novocain or alcohol may likewise be employed to advantage. The ligation of the proximal vein in an arteriovenous fistula where heart failure threatens, as in large fistulae, may be life-saving.

I quite agree that quadrant ligation and excision after a period of three to six months is the procedure of choice in the treatment of an arteriovenous fistula, since it allows time for the development of collaterals, and recurrence of infection is less likely than by any other method.

It must be borne in mind that cirsoid aneurysm is frequently initiated by trauma, particularly trauma to a port-wine blemish, and excision of such tumor should be carried out as soon as it is discovered.

RADICAL OPERATIVE TREATMENT FOR SUPPURATIVE PHLEBITIS, AND ITS RESULTS

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PHLEBITIS of the lateral sinus producing bacterial invasion of the blood stream is the classic example of an acute infection of the wall of a vein that is subjected to direct surgical treatment. Operations on the lateral sinus, with a view to the elimination of the infection of the blood stream, have been practiced for many years. Worth while results have been achieved despite the fact that difficulties which are peculiar to the otitic field are encountered. On the other hand, virtually no efforts have been made, according to the literature, to match the results obtained in operations for phlebitis of the lateral sinus by operations on other venous trunks which are similarly affected elsewhere. This appears to be a fact despite the comparative ease of operative exposure of some of these venous trunks and the greater likelihood which often exists of eradicating surgically the source of the invasion of the blood stream in such cases.

The reason for the apparent rarity of operative procedures for acute suppurative phlebitis of readily accessible veins such as the femoral or axillary must be found either in the assumption that they rarely are involved or that involvement by phlebitis rarely is the cause of the clinical picture of septicemia. Therefore, attention should be called to certain observations which have already been reported. In a study made in 1934, of 150 cases of septicemia with positive blood cultures, we[1] showed that acute phlebitis was demonstrable in almost one-half of all cases. It was probably present but not demonstrable for various reasons in many of the remaining cases. The area of phlebitis usually was situated in the main venous trunk in the affected region, such as the internal jugular, the popliteal, or the external iliac veins. In other words, phlebitis when present was to be found in some substantial vein regardless of whether or not its origin from some smaller venous radicle was demonstrable. Suppuration in adjacent soft parts was often found as the source of the infection of the vein. Phlebitis usually was extensive at the time of fatal termination, but even then (at autopsy) the lesion was capable of surgical eradication in not a few instances. The lesion of the vein most often was a suppurative thrombophlebitis, but acute phlebitis without thrombosis was not rare. The mortality in the 150 cases was exceedingly high. Thus, evidence was advanced a number of years ago to show that septic invasion derived from acute phlebitis of main venous channels in surgically accessible regions was not rare, and that the mortality attendant upon so-called conservative treatment of the lesion of the vein was exceedingly high. There is no present reason to materially alter this view, except insofar as specific chemotherapy is concerned. The clinical picture of septic invasion of the blood stream has been profoundly affected, the mortality has

been lowered, metastatic foci are rare, but according to personal observation, the incidence of suppurative phlebitis from which septic invasion of the blood stream may be derived, has not been greatly lowered.

Only brief reference need be made to some of the clinical features of acute phlebitis of the variety under discussion. There appear to be certain sites of predilection, the outstanding one being the axillary vein. In phlebitis derived from lesions in soft parts, there is present an abscess or suppurative lymphadenitis adjacent to the lesion in the vein or less frequently a cellulitis without areas of suppuration. The inflamed vein usually cannot be felt. Prostration is out of proportion to the apparent lesion, that is the abscess. Fever and prostration persist after adequate surgical drainage of such an abscess or similar suppurative focus. Chills, of course, are of sinister significance. However, it should be pointed out that they do not occur in many cases of proven phlebitis.[1]

Omitting a detailed consideration of the significance of blood cultures in the diagnosis of and operative indications for suppurative phlebitis, there are two points which I wish to make and which are exemplified in the tabulation of the operative cases. First, blood cultures not infrequently are negative in the presence of suppurative phlebitis amenable to surgical therapy, and secondly, there was no mortality among the operative cases with negative blood cultures. In the absence of a positive blood culture, an absolute diagnosis of suppurative phlebitis can rarely be made. On the other hand, as illustrated by Cases 4, 5, and 7 in Table I, the mortality inevitably will be high if an absolute diagnosis is awaited before proceeding with a surgical effort at cure.

TABLE I

CASES WITH POSITIVE BLOOD CULTURES* (NINE CASES)

Case No.	Local Pathology	Pathology of Vein	Chills	Result	Factors in Mortality
1	Cervical abscess	Acute phlebitis, with thrombosis of internal jugular vein	Chill	Recovered	
2	Axillary abscess	Suppurative thrombophlebitis of axillary vein	Chills	Recovered	
3	Pelvic cellulitis	Suppurative thrombophlebitis iliac vein	None	Recovered	
4	Cellulitis of hand and forearm	Acute thrombophlebitis of several veins of forearm	None	Died	Delayed therapy of phlebitis
5	Furuncles of lip and nose	Purulent thrombophlebitis of facial vein	Chills	Died	Late case. Metastases present
6	Hemorrhagic infiltration of axilla	Necrosis and thrombosis of axillary vein	None	Died	Fulminating course
7	Axillary abscess	Severe thrombophlebitis of axillary vein	Chills	Died	Delay after drainage of abscess
8	Cellulitis of neck and chest	Subacute proliferative phlebitis of axillary and subclavian veins	None	Died	Vein not accessible for excision
9	Lateral sinus thrombosis. Cellulitis of neck	Thrombophlebitis of internal jugular vein and phlebitis of innominate vein	None	Died	Vein not accessible for excision

* *Streptococcus hæmolyticus (Beta)*, Cases 1, 2, 3, 7, 8, 9. *Staphylococcus aureus*, Cases 4, 5, 6.

TABLE II

CASES WITH NEGATIVE BLOOD CULTURES (EIGHT CASES)

Case No.	Local Pathology	Pathology of Vein	Chills	Result
10	Axillary abscess	Organizing thrombo- and periphlebitis of axillary vein	None	Recovered
11	Suppurative axillary lymphadenitis	Acute periphlebitis of axillary vein	Chills	Recovered
12	Axillary cellulitis	Organizing periphlebitis axillary vein	Chills	Recovered
13	Cervical abscess	Acute purulent phlebitis and periphlebitis of external jugular vein	None	Recovered
14	Suppurative axillary lymphadenitis	Acute phlebitis and thrombosis of axillary vein	None	Recovered
15	Axillary abscess	Acute suppurative thrombophlebitis of axillary vein	None	Recovered
16	Cellulitis of foot	Acute purulent phlebitis and periphlebitis dorsal vein of foot	Chill	Recovered
17	Axillary cellulitis	Acute phlebitis of axillary vein without thrombosis	Chilliness	Recovered
		BLOOD CULTURES NOT TAKEN (TWO CASES)		
18	Cervical abscess	Acute phlebitis, without thrombosis of internal jugular vein	Chill	Recovered
19	Abscess of foot	Acute phlebitis and periphlebitis dorsal vein of foot	None	Recovered

Current methods of treatment of assumed or suspected cases of suppurative phlebitis can be summarized by stating that they consist of chemotherapy and of surgical drainage of a local abscess when it exists. Proximal ligation of the vein draining a suppurative focus appears to be favored by some authors. It is the direct attack on areas of surgically accessible phlebitis which I wish to advocate anew at this time. The procedure is not advocated for all cases. There are instances in which the lesion is inaccessible, and others in which an attempt at its eradication may be too hazardous. There are, however, cases in which involved veins are accessible surgically, the involvement is of limited extent, and complete excision is possible. As has been pointed out elsewhere,[2] nothing short of the removal of the segment of vein bearing the area of phlebitis will suffice. Since the problem that is faced is one in which life is in jeopardy, the possible damage as the result of excision of main venous trunks, specifically those of the extremities, is of secondary importance. In fact, however, experience has shown that there are insignificant, if any, ill results from the excision of such trunks. Thus, there may be complete absence of edema of an extremity following excision of sections of the axillary or of the external iliac veins. Another objection which has been made to the proposal to deal directly with areas of phlebitis has been the danger of opening up fresh avenues of infection. Although this undoubtedly is valid, theoretically, there have been no instances in actual practice in which untoward effects could be ascribed to this factor.

The principle of operation consists in adequate exposure of the suspected or obviously involved venous trunk and its excision beyond the visible limits of phlebitis, whenever possible. An examination of the tables will show that the vein was the seat of a suppurative thrombophlebitis in all cases with positive blood cultures. Thus, the lesion was readily discernible when the affected area of the vein was exposed at operation. On the other hand, the lesion

was not obvious in some of the cases with negative blood culture, and the question of management of the vein, therefore, requires special consideration in this group of cases. It is not only possible but probable that recovery might have ensued without excision of the vein in some cases in this group and the procedure, therefore, appears more debatable than in cases with positive blood culture.

The influence of chemotherapy on pyogenic sepsis is so profound, so many extraordinary recoveries take place to-day in cases which would have been fatal yesterday, that there is an almost unavoidable tendency to await the effect of chemotherapy alone in any case of pyogenic sepsis. In the present series of operated cases as well as in cases which did not come to operation are instances in which suppurative phlebitis was present and presumably had progressed despite specific chemotherapy. A few may be instances in which patients survived as the result of chemotherapy and in which a more or less localized phlebitis had the opportunity to develop, so to speak, because of survival. In any event, until evidence to the contrary is advanced, one must assume that sepsis due to suppurative phlebitis will or may persist despite chemotherapy and that, therefore, surgical measures for the eradication of the phlebitic process are warranted.

From a study of the tables it is evident that the best results can be anticipated in relatively early cases. At times good results will be obtained even in the severe and advanced lesions, and an effort at eradication of the infective focus in the vein should not be withheld even in the presence of already existent metastatic foci. The clinical condition and the possibility of eradicating the feeding focus are better guides to prognosis than the number of colonies in a positive blood culture. A negative blood culture should not lead to the conclusion to withhold operative intervention if there is clinical evidence to warrant exploration of a vein. A properly conducted exploration of a vein, if negative, is not harmful, whereas an overlooked phlebitis or one treated conservatively because the classic picture does not present itself, may lead to a fatal issue.

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HEPARIN ADMINISTRATION*

METHODS AND RESULTS IN THIRTY CASES

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DURING the past two years, 30 patients have been treated by general heparinization in the Henry Ford Hospital. In a previous paper,[1] the results in the first 11 cases were presented, a résumé of the history of heparin was given, and the various indications for heparin therapy were discussed. The literature on the subject of heparin has become large, as will be seen from the bibliographies appended to the review by Mason[2] and the monograph by Jorpes.[3] The largest clinical experience has been that of Murray[4] and others, at Toronto, where more than 700 patients have been treated with the material.

In this series of 30 cases, heparin was administered for the following conditions: (1) Postoperative embolism which was not immediately fatal, 24 cases; (2) embolism of a peripheral artery with embolectomy, three cases; (3) luetic thrombosis of the posterior tibial artery, one case; (4) hemiplegia from occlusion of the common carotid artery, one case; and (5) phlebitis, one case.

The gross results will be summarized at this time. Twenty-two of the 24 embolism patients recovered. The two deaths will be analyzed below; one of them apparently represents a failure of heparin in the dosage employed to prevent the recurrence of embolism. The circulation was restored to the legs in two of the embolectomy cases; the third lived only a few hours after an attempted removal of clots from the femoral artery. No flow of blood was obtained, and the grave condition of the patient, who was in the terminal stages of arteriosclerotic heart disease and appeared to have mesenteric embolism also, caused the operative interference to be interrupted without an abdominal approach to the iliac artery. A gratifying result was obtained in the case of luetic thrombosis of the posterior tibial artery,[1] and the one case of phlebitis showed transient amelioration. The patient with hemiplegia from occlusion of the common carotid artery was not benefited by heparinization, and expired.

The general plan of heparin treatment is to elevate the clotting time of the blood to an arbitrary optimum level, in the hope that dangerous clotting may be inhibited. The usual method is to administer the material in a continuous intravenous drip. Under ideal circumstances, this results in a prolongation of the clotting time which neither goes far above nor far below the optimum level. Chart 1 shows what might be termed an ideal heparin

* Read at the First Annual Assembly of the Central Surgical Association, Ann Arbor, Mich., February 28–March 1, 1941.

reaction, with the clotting time being kept at approximately 15 minutes (capillary blood in capillary tubes) by the administration of slightly more than 1,000 units of Connaught heparin per hour. The term "2 per cent solution" on the chart indicates that one 10 cc. vial of heparin was added to each 500 cc. of physiologic saline solution. One hundred milligrams of crystalline heparin is contained in each 10 cc. vial. Hence, the patient received about 1,200 cc. of physiologic saline solution daily.

Chart 2 is included to show two things: first, the results of a clinical trial of a brand of heparin prepared in this country (Liquaemin, Roche-

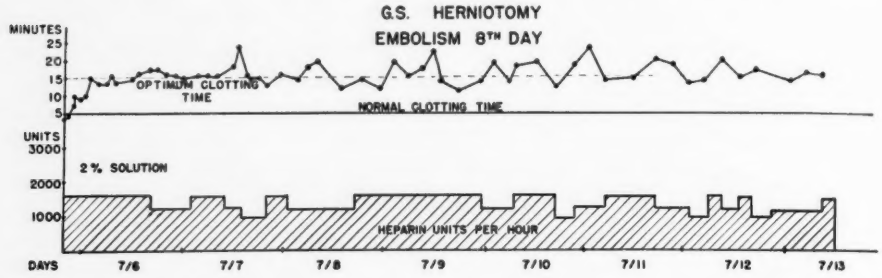

CHART 1.—Heparin chart of patient showing good response of clotting time to the administration of approximately 1,000 units of heparin per hour.

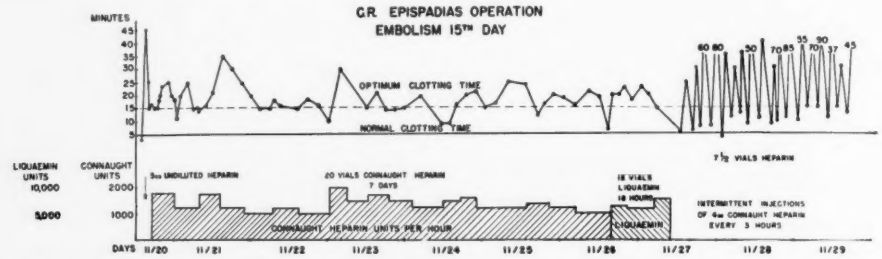

CHART 2.—Heparin chart showing the potency of the Liquaemin brand of heparin, and the effect of repeated injections of undiluted Connaught heparin.

Organon); and second, the effect of intermittent injections of the undiluted material. At that time, Liquaemin was marketed in 5 cc. vials, containing 10,000 units, but this unit is of a potency of only one-fifth that of Connaught heparin. Therefore, five vials (25 cc.) of this material were needed to produce the effect of one 10 cc. vial of Connaught heparin. Recently, Liquaemin has been dispensed in a 10 cc. vial containing 100 mg. of heparin.

Chart 2 also illustrates the effect of intermittent injections at intervals of three hours. McClure and I[1] showed that it was possible to do this without dangerous bleeding. The case reported developed embolism after prostatectomy, and received a course of heparin by the usual continuous intravenous route. Five days after the heparin was discontinued, he had a second small embolism. On account of the presence of mild cardiac decompensation, it was deemed inadvisable to give any saline solution intravenously, and the patient was given the undiluted material, in the amount of 4 cc. of Connaught heparin every three hours. The clotting time was frequently over an hour,

returning to 15 minutes or below in the three-hour period. This method is of value in the last few days of any course of heparin treatment, when it is advisable to have the patient get out of bed and walk without being encumbered by the intravenous apparatus.

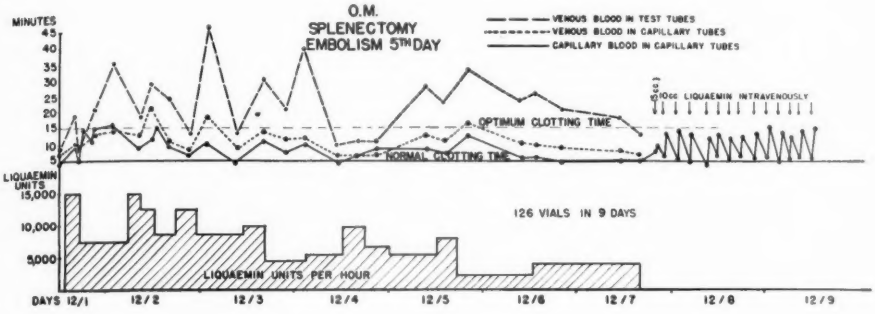

CHART 3.—Chart of patient treated with Liquaemin, with parallel clotting time determinations by three methods.

Chart 3 illustrates one of the problems in heparin treatment, namely, the problem of clotting time methods. This is the chart of a patient who was treated with Liquaemin for a period of eight days. During the time when he was receiving the material by continuous intravenous drip, the clotting time was taken at intervals by three methods; namely, venous blood in test tubes, venous blood in capillary tubes, and capillary blood in capillary tubes. It can be seen that the clotting time as measured by the test tube technic was easily maintained at 15 minutes or above by the administration of small amounts of Liquaemin. However, considerably larger quantities would have been necessary to elevate the clotting time to 15 minutes as measured with capillary blood in capillary tubes. Venous blood in capillary tubes occupied an intermediate position. Many of the reports on heparin treatment are not clear on the matter of the clotting time method. In their original directions for heparin treatment, Murray and Best[5] advised that the clotting time be elevated to 15 minutes as measured by the capillary tube method. Recently, Murray[6] states that they are using venous blood in a 1 cc. test tube, with a glass bead for an indicator. The directions accompanying the Liquaemin preparation suggest the use of the Lee and White method, in which venous blood is placed in several test tubes, which are inverted until clotting occurs, the clotting time in the fifth tube being taken as the reading. The determinations on Chart 3 were made with two test tubes. Obviously, reports on heparin treatment should state clearly the clotting time method used, if evaluations of the potency *in vivo* are to be made. At the present time, no one is willing to state what is the actual optimum clotting time to prevent thrombosis. The expense of heparin is such that one wants to use the least amount that will produce the desired effect. The case report which follows, taken alone, would cause one to try to maintain a clotting time of at least 15 minutes by the *capillary tube* method.

Case 1.—The patient was an obese woman, age 43. She had drainage of an appendiceal abscess of 11 days duration on April 24, 1940. The postoperative course was stormy, with distention being a troublesome complication. Thus, many factors favoring embolism were present, namely, several weeks of recumbency in bed, infection, obesity, and increased intra-abdominal pressure from distention to retard back-flow from the veins of the legs. On May 25, 1940, one month after operation, and after orders had been left for her to get up the next day, she had a sudden attack of epigastric pain, sweating and shortness of breath. The diagnosis of pulmonary embolus was obvious, and heparin was begun. Large amounts of heparin were necessary to keep the clotting time near 15 minutes (Chart 4). The condition of the patient improved rapidly and heparin was to be discontinued on June 2, 1940, after one week of treatment. However, at 3:45 A.M. on this day, she awoke with dyspnea and a hacking cough which was productive of blood-streaked sputum. The condition of the patient grew steadily worse; there was marked air hunger and the skin was cold and moist. She was treated with oxygen, papaverine, morphine, and increased amounts of heparin, but she expired about 24 hours after the onset of the episode. Postmortem was refused, although it was sought with great diligence. From clinical examination, death appeared to be due to a second massive pulmonary embolism. However, acute heart failure could not be entirely ruled out.

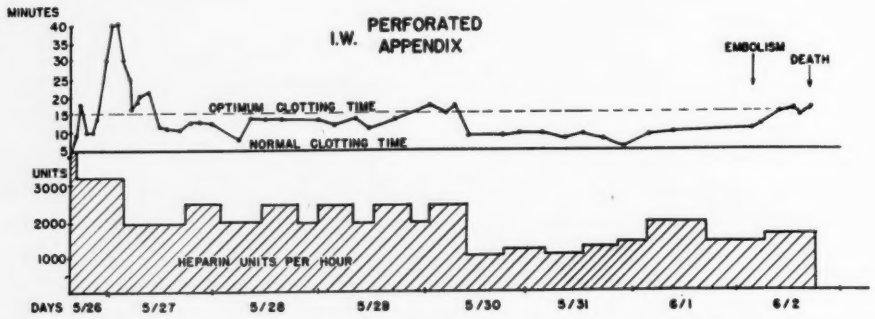

CHART 4.—Heparin chart of patient who apparently had a second pulmonary embolism in the midst of heparin therapy.

Fortunately, an accurate record of the amount of heparin given and the clotting times had been kept. This record showed that for about two days, the clotting time was ten minutes, and on one occasion it got as low as six minutes. Did a clot form during this brief period? Did a piece break off an old thrombus which had been waving in a large vessel for more than a week? Regrettably, the answer in this particular case can never be known. More information was obtained regarding the second fatality during heparin administration, because an autopsy was obtained.

Case 2.—The patient was a man, age 69, who was admitted to the hospital on the Medical Service of Dr. Robert Durham. The provisional diagnosis was arteriosclerotic heart disease with fibrillation. He had two pulmonary embolisms, thought to have come from the right auricle, although the presence of femoral phlebitis was discovered later. He had marked dyspnea, and was heparinized as a last resort. He expired in one week, with signs of cardiac failure. Autopsy showed huge infarcts of the lungs, which were thought to be at least one week old. The cardiac muscle showed gross evidence of degeneration. No hemorrhagic manifestations were discernible.

The complication of hemorrhage has not been prominent in the previous reports. In 315 cases reported by Murray and Best,[7] there were four instances

of hematoma formation in the wound, with the result that heparinization was stopped. Priestly, Essex and Barker[8] noted only transient hematuria a few times in their 45 cases.

In this series, there was hemorrhage from the operative wound four times. Two patients bled from wounds in the popliteal space following embolectomy. Fortunately, the hemorrhage did not begin until four days had elapsed in each case, and the arteries remained patent, even though the heparin was discontinued. The third patient had a rather extensive dissection of the abdominal wall for the excision of a draining sinus. Three days later, he had pain in the chest suggestive of infarction and the next day heparin treatment was begun by the intermittent method, on account of the presence of cardiovascular insufficiency. Four cubic centimeters of Connaught heparin was given every three hours, and the clotting time rose to 20–30 minutes after each injection, the maximum being 46 minutes on one occasion. An hematoma developed on the second day, and the heparin was discontinued, inasmuch as sputum studies indicated that the pain in the chest was due to bronchopneumonia rather than embolism. The fourth patient had pain in the chest on the twelfth day following hysterectomy. Heparin was started, but was given in abnormally large amounts for several hours, with the result that the clotting time was 65 and 75 minutes on two occasions. The patient began to bleed from the vagina after 24 hours of treatment, and this was controlled with some difficulty by stopping the heparin and packing the vagina. One transfusion was given. Recovery was rapid.

There was one case of concealed hemorrhage. A very obese woman, age 42, had a spinal fusion. During the third week of convalescence, she had several small pulmonary embolisms. Heparin was begun, by the use of a continuous intravenous cannula placed in a vein on the medial side of the left ankle. The right leg is usually used for this procedure, on account of the propensity of the left for phlebitis, but in this case a bone graft had been removed from the right leg, so the left was chosen. The clotting time was maintained at the optimum level by giving 1,000 units of heparin per hour (Chart 5). On the third day of treatment, the patient complained of severe

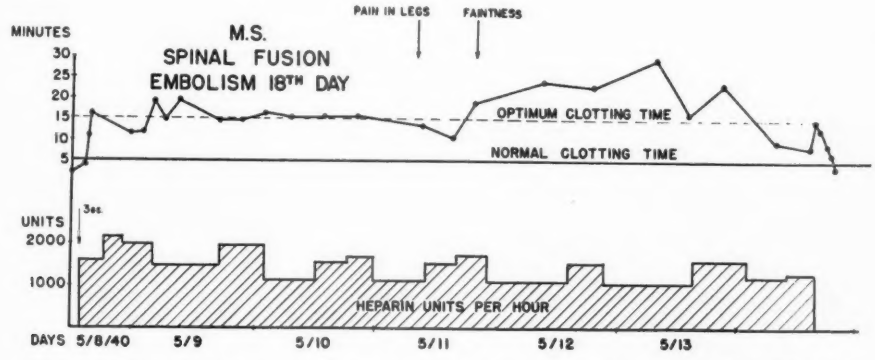

CHART 5.—Heparin chart of patient who developed a massive hematoma in the thigh (Fig. 1).

pain in the region of the femoral vessels of the left leg. The leg was repeatedly examined, and no cause for the pain could be found. Later, she complained of feeling faint. The true state of affairs was not recognized until three days later, when bulging in the left thigh was noted (Fig. 1). The

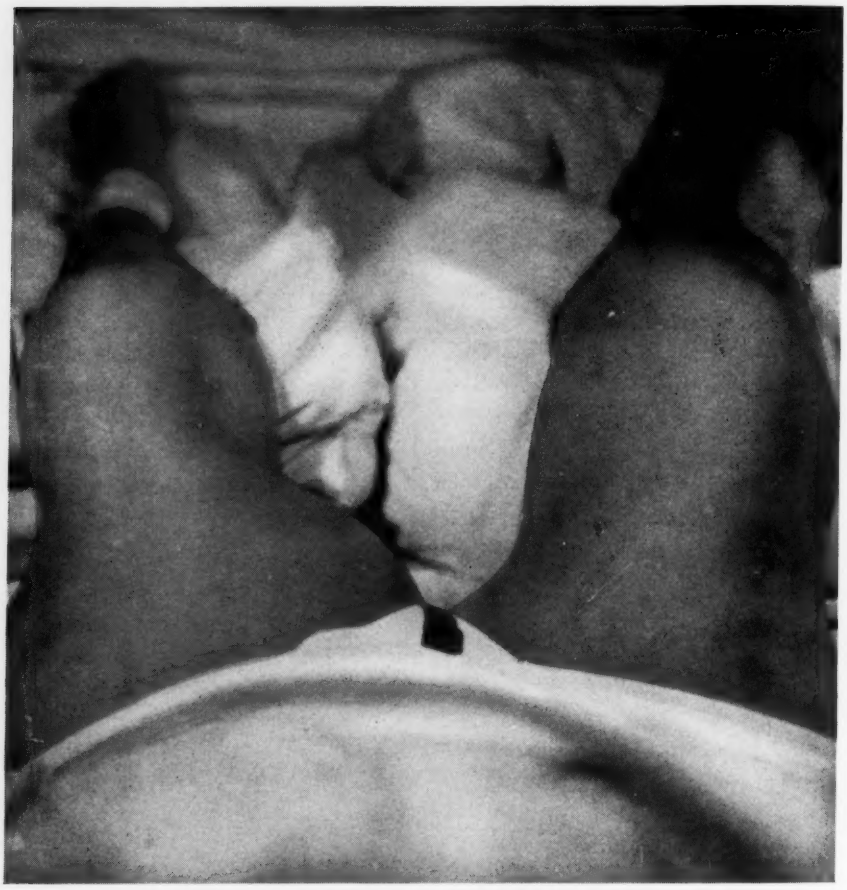

FIG. 1.—Photograph of legs of the patient who developed an huge hematoma in the left leg on the third day of heparin administration.

hemoglobin determination at this time showed 5 Gm., or 33 per cent. It was obvious that the swelling represented a massive hematoma which had come from an unknown source in the leg. It is of interest to note that the vitamin C on the patient this day was 0.20 mg., which is about scurvy level, and there was evidence of capillary fragility by the tourniquet test. Apparently the combination of the two hemorrhagic tendencies resulted in the subcutaneous bleeding.

COMMENT.—It has not been my intention to paint a dark picture for heparin therapy. I have mentioned the complications, having little to say about the other cases who comprise the majority of the series, who had uninterrupted recoveries after having had one, two, and even three previous

pulmonary infarcts. Heparin has a place in the treatment of thrombosis. Its value in embolectomy and other kinds of blood vessel surgery is even greater. However, those who use heparin should keep in mind such reports as that of Potts,[9] who carried 518 patients through various operative procedures with no clinically recognizable evidence of thrombosis or embolism, by simply making them carry out a simple exercise in bed! Still more puzzling is the report of Reed,[10] who stated that he had deliberately *reduced* the clotting time in a series of operative cases, by the administration of adrenal cortical extract. He had had no embolism or thrombosis in over 200 cases!

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PECTIN SOLUTION AS A BLOOD SUBSTITUTE

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The present war has reemphasized the urgent need for blood and blood plasma in the fluid or desiccated state, which may be used to combat shock and hemorrhage. In line with other defense work, the collection of desiccated plasma for our own armed forces has been undertaken by the American Red Cross under the supervision of the National Research Council. The present specifications covering the preparation of this material require the desiccation from the frozen state. With the largest units desiccating from the frozen state, such as used by Best at the Banting Institute, only 1,000 units of 250 cc. each can be produced per week. Even with our method[1] of desiccation from cellophane cylinders with a production of 1,200 units of 250 cc. per week, the matter of obtaining such large quantities of human blood remains a great problem. From the standpoint of production alone, to say nothing of cost, transportation, storage, and application, it seems obvious that some other substances which may be used as substitutes or supplements for blood and blood plasma must be found.

The widespread and successful use of blood plasma and blood serum in shock and hemorrhage has demonstrated most convincingly that the primary need in such emergencies is to replenish the volume of circulating fluid with a fluid which has identical or similar physical characteristics rather than new red blood cells. The red blood cells may in fact be distinctly contraindicated in shock without hemorrhage.[2]

In a recent article, Taylor and Waters[3] outline the requirements of a transfusion fluid which will restore and maintain the volume of circulating fluid as follows: "(a) The molecule of the dissolved substance must be of such a size that the fluid will not leave the vessels too freely. (b) The solution must exert an osmotic pressure and possess a viscosity approaching as closely as possible that of whole blood; these qualifications depend upon molecular size and shape. (c) It should be as nearly as possibly isotonic with the contents of erythrocytes. (d) It must, of course, be nonantigenic and innocuous in every respect. In addition, it should be readily available, preferably cheap, and capable of being quickly and easily prepared for intravenous administration."

To meet these requirements, Taylor and Waters propose the use of isinglass (fish gelatin) especially prepared from fish swimming-bladders. Some difficulty in purification has been encountered, but in animal experiments it seems to answer the purpose and only a few reactions were encountered. It

is held superior to ordinary gelatin which does have definite antigenic properties.

The second colloidal material which has been widely used as a blood substitute is gum acacia. Its use was suggested by Bayliss,[4] in 1916 under the title "Methods of Raising a Low Arterial Pressure," and supported by Rous and Wilson,[5] in 1918 under the title "Fluid Substitutes for Transfusion after Hemorrhage." The favorable results reported by Bayliss and Rous and Wilson were confirmed by some investigators and objections were brought out by others. Hanzlik and Karsner,[6] in 1922 in a study of various colloids state regarding acacia: "It injures the circulatory and respiratory systems as indicated by the presence of anaphylactoid symptoms, pulmonary distention, congestion and hemorrhage together with cardiac dilatation. Thrombi in the pulmonary vessels occurred after the injection of acacia in therapeutic doses and concentrations." Maytum and Magath[7] in 1932 confirmed the fact that even the best solutions might be antigenic: "Solution of acacia is a mild antigen . . . there is no danger in the first dose of acacia but subsequent doses should be given cautiously because of the possibility of anaphylactic reactions." Yuile and Knutti[8] in 1939 showed that the livers of dogs injected weekly with acacia may increase five to six times in weight and contain 8 to 10 per cent of acacia by weight. Further it was found that acacia persisted as long as 144 days in the blood and that the plasma proteins were depressed to very low levels, particularly the fibrinogen fraction which remained low for several months.

Andersch and Gibson[9] report that 30 per cent of the injected acacia was found in the livers of dogs and 43 per cent of 46 Gm. injected was found in the liver of a nephrosis patient.

Jackson and Frayser[10] in 1939 found that "the fibrinogen may become very low and cause considerable delay in clotting and prolongation of bleeding if large amounts of acacia are given."

Thus it is apparent that while acacia satisfies the first three requirements, it fails in the fourth since it is antigenic and is stored in the liver, interfering with liver function.

The difficulties encountered in the intravenous use of acacia have been detailed because it is obvious that any new colloidal solution proposed for intravenous use in shock and hemorrhage must eliminate most or all of these disadvantages, if it is to be a truly acceptable substitute for whole blood or blood plasma.

Pectin is a substance very familiar to the profession but its therapeutic application has been confined to the skin and intestinal tract. It may be described, according to Gortner[11] as a colloidal carbohydrate of high molecular weight and rather complex composition. On hydrolysis it is said to produce galacturonic acid, galactose, arabinose, xylose, methanol, and acetic acid. Protopectin is the mother substance of the pectins and both are found in the plant cell walls where they are probably combined with cellulose. Protopectin may be hydrolyzed free from the cellulose and converted into

soluble pectin, usually by treatment with 0.5 per cent ammonium oxalate at 70 to 90° C. or by heating with dilute acids. The pectin resulting from either form of hydrolysis is of high molecular weight, disperses in water to a viscous colloid solution and is readily precipitated from this solution by alcohol.

Myers and Baker[12] believe that lemon pectin is monoarabinomonogalactodiacetylheptamethoxyloctagalacturonic acid, giving a formula of $C_{70}H_{98}O_{58}$ with a molecular weight of 1,866. Bonner[13] suggests a cellulose-like chain formula. Henglein and Schneider[14] nitrated pectin and found the resulting material with the physical characteristics similar to nitrocellulose.

Source and Preparation of Pectin for Intravenous Use.—Pectin in the dry powder form obtained from two manufacturers was used in this work. One brand bore the label "pure grapefruit pectin" and the other "pectin-technical grade." The former, designated as Brand I, is a light brown granular material which is sufficiently soluble in warm, double distilled water to readily make a 1 per cent solution. It is filtered through No. 1 Whatman papers. This solution is slightly opalescent and has a pH of 3.05. Its viscosity is 10.15 at 38° C. and its osmotic pressure is 50 Mm. of mercury. Since the viscosity of whole blood is about six and the osmotic pressure of plasma is 25 to 30 Mm. of mercury, the 1 per cent solution of Brand I is diluted with equal quantities of 1.8 per cent NaCl or double strength Ringer's solution; then phosphate buffers are added in sufficient quantity to bring the pH to 6.5. The pectin obtained from the second manufacturer, Brand II, is a white powder which contains 35 per cent glucose. Because of the difficulty in separating this glucose, the material was used in a 1 per cent solution made up in double distilled water. It is filtered through No. 1 Whatman papers. This solution has a viscosity of 3.5 and an osmotic pressure of 22 Mm. of mercury. Eight-tenths of 1 per cent NaCl and phosphate buffers are added to bring the pH to 6.5. Both solutions are sterilized under steam pressure of 15 pounds for 20 minutes. After sterilization, the solutions are still slightly opalescent and is further buffered to pH 7.2. As with other colloidal solutions, every lot does not turn out alike, therefore it is necessary to test each lot against citrated blood and suspensions of red blood cells, examining for hemolysis, rapid sedimentation, and precipitation of fibrin. If any of these occur the solution must be rejected.

Experimental.—No evidence has been found in the literature to indicate that pectin is an antigenic substance, but since it has not been used intravenously as a therapeutic agent, it seemed desirable to determine whether or not it was antigenic or whether it would produce so-called anaphylactoid symptoms. To this end three guinea-pigs were injected intravenously with 1 cc., 1.5 cc. and 2 cc. of the 1 per cent buffered pectin solution and at the end of 14 days with the same amounts intravenously. No reaction occurred.

Twelve rabbits of six and eight pounds each were given 1 per cent buffered pectin solutions intravenously in amounts ranging from 50 to 100 cc. These doses were repeated after one week and after two weeks, but no immediate

or delayed reaction occurred. Three dogs, as indicated in Table I, were injected four times over a 26-day period with 1 per cent buffered pectin solution in doses ranging from 300 to 350 cc., each time without anaphylactic symptoms.

TABLE I

LIVER FUNCTION FOLLOWING PECTIN INJECTION

Dog, and Wgt.	Date 1941	Gm. Pectin per Kg.	B.S.P. Liver Function Test		
			5′	10′	20′
P 60					
15.8 Kg.	6/12	0.19	....	....	....
	6/17	0.22	....	....	....
	6/18	....	50%	30%	20%
	6/21	....	25%	15%	neg.
	6/23	0.19	....	....	....
	7/7	0.25	....	....	....
	7/7 (4 hrs.)	....	40%	20%	10%
	7/8 (24 hrs.)	....	40%	20%	7%
	7/11	....	35%	10%	neg.
P 70					
11.3 Kg.	6/12	0.26	....	....	....
	6/17	0.26	....	....	....
	6/18	....	45%	20%	15%
	6/21	....	35%	10%	neg.
	6/23	0.26	....	....	....
	7/7	0.35	....	....	....
	7/7 (4 hrs.)	....	55%	25%	15%
	7/8 (24 hrs.)	....	60%	25%	10%
	7/11	....	35%	5%	neg.
P 80					
17.7 Kg.	6/12	0.17	....	....	....
	6/17	0.17	....	....	....
	6/18	....	45%	15%	5%
	6/21	....	25%	10%	neg.
	6/23	0.17	....	....	....
	7/7	0.23	....	....	....
	7/7 (4 hrs.)	....	50%	35%	20%
	7/8 (24 hrs.)	....	30%	15%	10%
	7/11	....	25%	5%	trace

The disposition of pectin in the body after it is injected intravenously is of primary importance, since one of the principle difficulties with acacia is its retention in the blood and tissues, especially in the liver. Pectin is also taken up by the liver, especially if a single large dose is administered. In six to eight pound rabbits receiving 100 to 150 cc. of the 1 per cent buffered pectin solution at one time and sacrificed three hours later, there was no marked gross enlargement of the liver, but microscopically the hepatic cells appeared swollen and filled with small clear granules. A dog of 16 Kg. receiving 425 cc. of 1 per cent buffered pectin solution, and autopsied 14 hours later, failed to show either gross or microscopic evidence of liver retention. As seen in Table I, the fractional bromsulphthalein test of liver function after the injection of large amounts of pectin solution showed a temporary blocking which

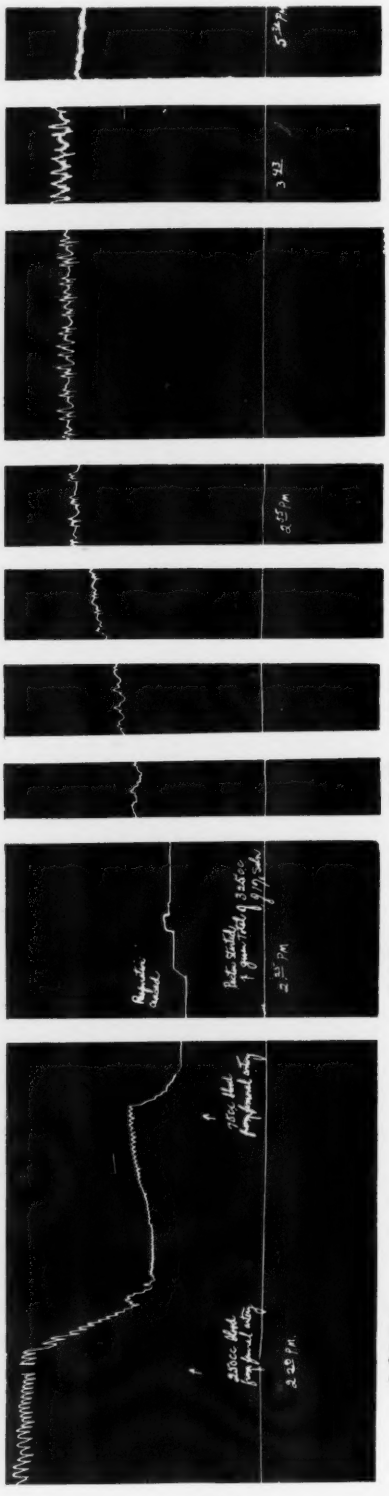

FIG. 1.—Experiment upon dog weighing 11.8 Kg. Effect of intravenous injection of 325 cc. of 1 per cent pectin in shock produced by bleeding of 325 cc. of blood. The final blood pressure is 160 Mm. of mercury.

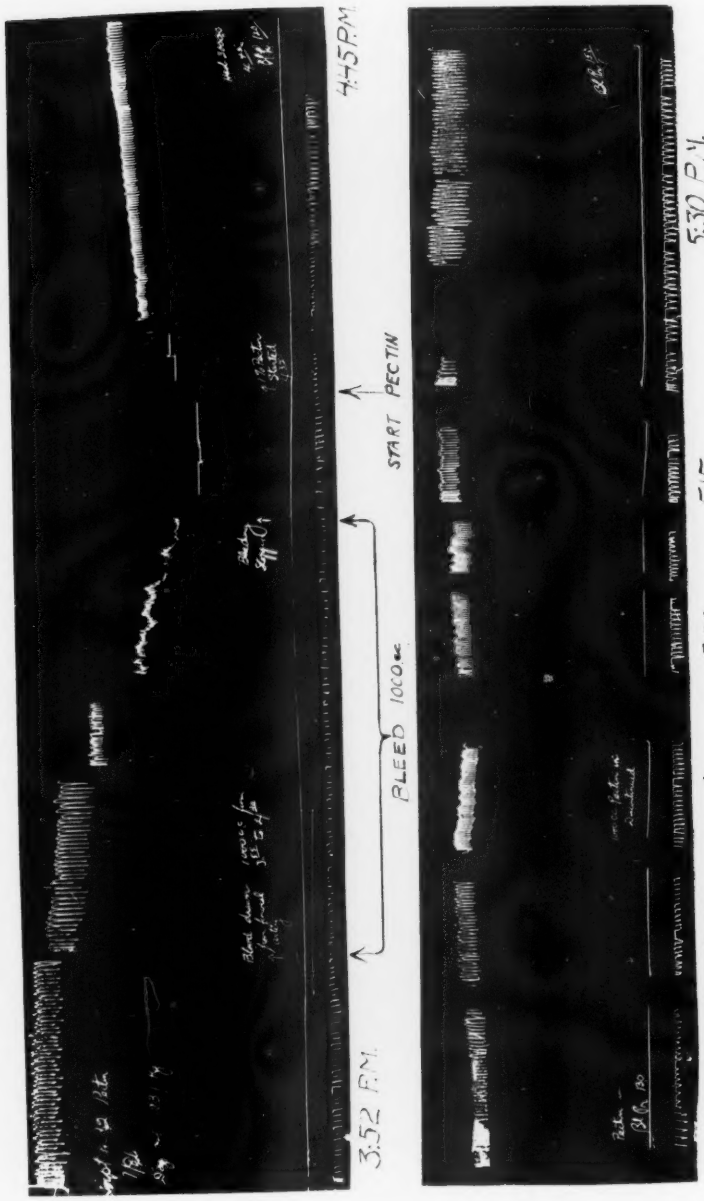

FIG. 2.—Experiment upon dog weighing 23.1 Kg. Effect of intravenous injection of 1,000 cc. of 1 per cent pectin in shock produced by bleeding of 1,000 cc. of blood. The final blood pressure is 160 Mm. of mercury.

cleared rapidly and showed no tendency toward a cumulative storage or blockage even with four large doses in a 26-day period.

The temporary character of the body's retention of pectin is demonstrated further by its excretion in the urine. It is excreted unchanged, as demonstrated by precipitation when equal quantities of urine and absolute alcohol or urine and acetone are mixed. In either case the pectin is thrown down as a white flocculant precipitate. A rough quantitative estimation of the amounts may be made by comparing with a known solution which has been precipitated in the same manner. The excretion of pectin is small for the first eight to 12 hours after the injection but reaches the maximum within 24 hours, and within 48 to 72 hours the major portion of the pectin is eliminated.

Considering the source, method of production, and chemical nature of pectin, there is nothing to suggest that it would be toxic for the body or its component units. Further, pectin has been used extensively in man as a local application to wounds and in the gastro-intestinal tract without toxicity. With solutions prepared and tested as described, there have been no indications of toxicity in either man or animal. Pectin solutions which are not properly adjusted as to the pH and which have a viscosity above five are poorly tolerated in animals and must be guarded against in clinical work.

A series of 12 experiments were performed upon animals in order to assay the value of pectin for blood replacement in shock following (a) hemorrhage; and (b) experimental bile peritonitis, and observe its effect on (c) blood concentration; and (d) as a replacement for plasma in plasmapheresis.

(a) In four animals, shock was produced by *hemorrhage*. As seen from Table II, the amounts of blood removed, while considerable, were not sufficient to alone cause death in all instances, but the effects of pectin in restoring blood pressure are quite striking. As seen from Figures 1 and 2, the restored level of blood pressure was well maintained after the administration of pectin solution intravenously.

TABLE II

THE USE OF PECTIN IN SHOCK FOLLOWING EXPERIMENTAL HEMORRHAGE

Experiment No.	Dog Wt. Kg.	Initial Blood Pressure Mm.Hg.	Bled cc.	Blood Pressure After Bleeding Mm.Hg.	Inject cc. 1% Pectin Intravenously	Final Blood Pressure Mm.Hg.	Result
1	11.8	110	325	80	320	155	Died. Lung abscesses found at necropsy
2	12.2	150	375	50	475*	130	Recovered
3	13.6	138	500	90	500†	110	Recovered
4	23.1	180	1,000	80	1,000	160	Recovered

* Plus 150 cc. whole blood.

† One-half per cent pectin used in this experiment.

(b) Five animals with *bile peritonitis* were treated with pectin. The bile peritonitis was produced by the intraperitoneal injection of sterile 10 per cent solution of Armour's repurified bile salts. A marked hemoconcentration as

evidenced by a rise in the hematocrit resulted. This rise and the associated marked fall in arterial blood pressure are shown for a typical experiment in Table III. Three animals in this stage were then treated with intravenous

TABLE III

THE USE OF PECTIN IN SHOCK FROM BILE PERITONITIS

Typical Experiment. (In the other two experiments the animals lived ten plus and 22 hours after injectin the bile salts intraperitoneally.)

Dog weight—11.8 Kg.
Initial readings: Blood pressure—140 Mm.Hg.; hematocrit—46%.
Inject 89 cc. 10% bile salt solution intraperitoneally.
Time interval—3¾ hours.
Subsequent readings: Blood pressure—60 Mm.Hg.; hematocrit—69%.
Inject 230 cc. 10% pectin intravenously.
Later readings: Blood pressure—128 Mm.Hg.; hematocrit—58%.
Death six hours after intraperitoneal bile injection.

pectin injections as shown in Figures 3 and 4, and a temporary improvement in hematocrit reading and blood pressure level occurred. These experiments were made to observe this effect rather than to attempt a permanent cure since it is well known that in instances of bile peritonitis of this severity even plasma will not prevent death.[15]

TABLE IV

PECTIN PLASMAPHERESIS EXPERIMENT, JULY 5, 1941

Dog Weight 11.8 Kg., Nembutal Anesthesia

	Observation				Remove Cc.			Administer Cc.	
		Gm./100 Cc.							
Time P.M.	Hematocrit	Albumin	Globulin	Total	Whole Blood	Cells	Plasma	Cells	1% Pectin
4:12	41	3.39	1.52	4.91	...	...	..	...	...
4:18	..	....	....	....	200	105	95	...	...
4:45–5:00	..	....	....	....	...	...	..	105	130
5:02	45	2.09	1.73	3.82	...	...	..	...	...
5:05	..	....	....	....	175	95	80	...	...
5:11–5:31	..	....	....	....	...	...	..	95	130
5:35	45	1.76	1.84	3.60	...	...	..	...	...
5:37	..	....	....	....	175	105	70	...	...
5:38–6:03	..	....	....	....	...	...	..	105	100
6:07	50	2.09	1.09	3.18	...	...	..	...	...
6:08	..	....	....	....	175	105	70	...	...
6:09–6:31	..	....	....	....	...	...	..	105	100
6:32	52	1.97	0.87	2.84	...	...	..	...	...
				Totals	725	410	325	410	460

Two other animals were given pectin before the production of bile peritonitis with no demonstrable prolongation of life over that observed in similar control experiments.

(c) In one experiment, pectin solution was rapidly injected to see if it could cause a blood *concentration* or dilution. A rapid dilution was observed, unlike the paradoxic blood concentration following concentrated plasma injections observed by Harkins, Boals and Brush.[16] In this same experiment, frequent determinations of the blood clotting time were made with no demonstrable prolongation being observed.

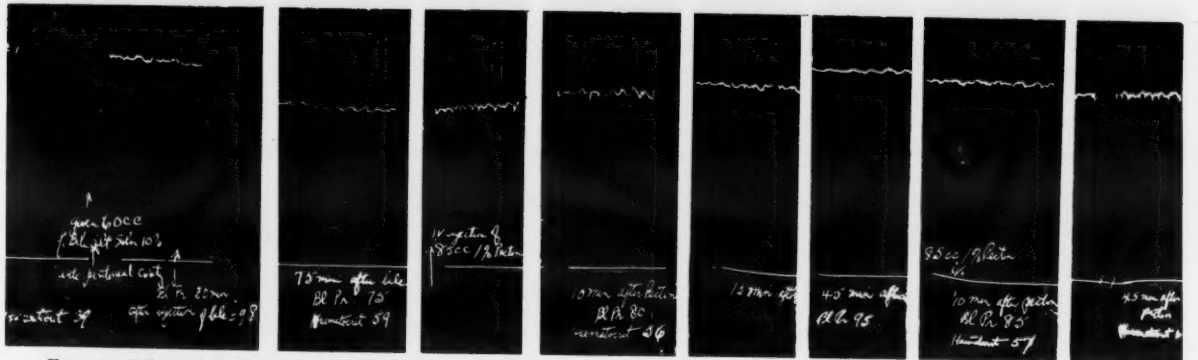

FIG. 3.—Effect of intravenous injection of 255 cc. of 1 per cent pectin in shock produced by the intraperitoneal injection of 60 cc. of 10 per cent sterile bile salt solution. The hematocrit rose from 39 to 59 before pectin was given and then fell to 56. It later rose to 62. The last blood pressure shown on the chart, 45 minutes after pectin administration, is 136 Mm. of mercury. The animal died 22 hours after production of the peritonitis.

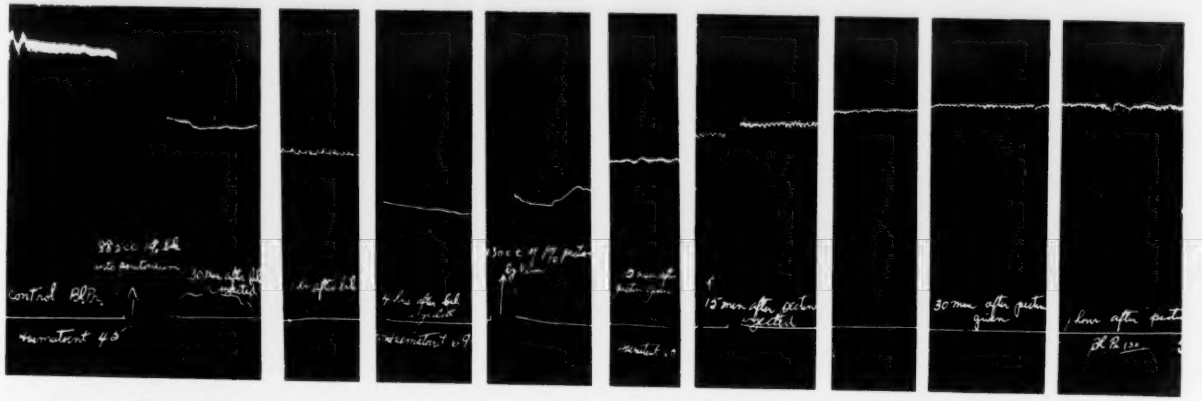

FIG. 4.—Effect of intravenous injection of 230 cc. of 1 per cent pectin in shock produced by the intraperitoneal injection of 89 cc. of 10 per cent sterile bile salt solution. Accompanying hematocrit readings are shown in Table II. The last blood pressure shown on the chart, one hour after pectin administration, is 162 Mm. of mercury. The animal died six hours after production of the peritonitis.

(d) In two dogs, *plasmapheresis* was done. After centrifuging withdrawn samples of blood, the plasma was discarded and replaced by an equal or slightly greater amount of 1 per cent pectin solution. The cell-pectin mixture

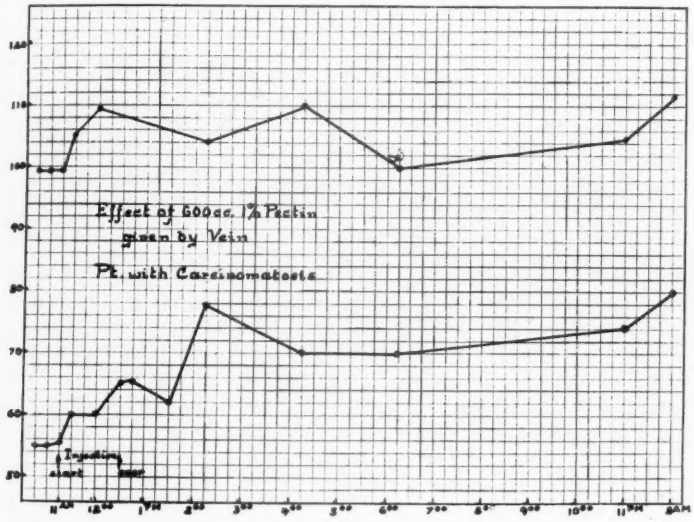

FIG. 5.—Case 1: Effect of intravenous injection of 600 cc. of 1 per cent pectin in patient B. M.

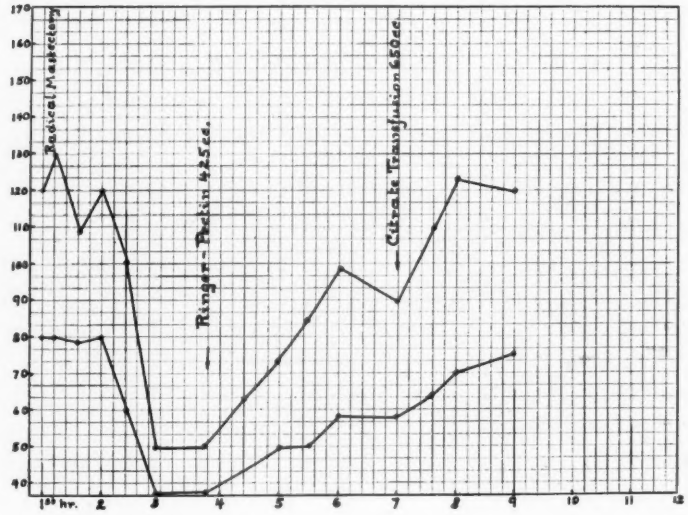

FIG. 6.—Case 2: M. W. No. 16863. A female, white, age 42. Weight 130 lbs. Lump in right breast for three months. Admission blood pressure 140/85. Operation July 1, 1941—Radical mastectomy with skin graft from right thigh. (Preoperative hemoglobin 12.5 Gms.) Anesthetic ethylene. Received 450 cc. of 1 per cent pectin solution intravenously after returning from the operating room in shock. Condition improved and the systolic blood pressure rose from 50 to 98.

was then immediately reinjected in the animal. This procedure was repeated a total of four times in one experiment and five times in the other, withdrawing samples of about 200 cc. of blood each time. In one experiment, the hematocrit did not vary at all, while in the other, it increased somewhat as seen in Table IV. The marked decrease in total plasma proteins following pectin replacement in this animal is noteworthy.

CLINICAL OBSERVATION

Case 1.—*Pectin Injection in Patient Not in Shock:* B. W., a female, age 54, had a palliative operation for carcinoma of the right breast, October 8, 1940. She returned to the hospital, June 30, 1941, with multiple metastases. An intravenous injection of 600 cc. of 1 per cent pectin was given, July 3, 1941. The chief effects were a slight feeling of well-being and an elevation of blood pressure from a mild hypotensive to a more normal level as shown in Figure 5. A slight chill with a transient temperature elevation to 101.4°F. might well be attributed to a coincident bromsulphthalein test. Furthermore, the patient had a daily diurnal rise to 99.0° F. each day before the pectin administration. Liver function and renal function tests were performed before and after the giving of pectin. On July 2, 1941, the bromsulphthalein retention was ten minutes—10 per cent, 20 minutes—0, and 30 minutes—0, and on July 4, the day after pectin injection, the test was exactly the same. A phenolsulphonphthalein test on July 2 showed 65 per cent excretion in one hour and 15 per cent in the second hour for a total of 80 per cent. On July 4, the day after pectin injection, the readings were identical. Hematocrit readings were constant (decrease from 38 to 37) and the clotting time also showed no appreciable change. Blood protein analyses, in grams per cent, were as follows:

	Albumin	Globulin	Fibrinogen	Total
July 2, 1941 (before pectin)	4.04	2.27	0.40	6.71
July 3, 1941 (just after pectin)	1.98	4.17	0.43	6.58

The clinical use of pectin in shock is illustrated in Figures 6, 7 and 8.

Discussion.—The use of pectin as the colloid base for a blood substitute is logical because it is one of the most hydrophilic colloids, only 0.5 Gm. of pure material per 100 cc. of solution being required to make a solution with a viscosity and osmotic pressure near that of whole blood. Thus, 14 times more acacia, gelatin or isinglass, gram for gram, is required to make a suitable intravenous solution, than is required with pectin.

The source—citrous fruits—and the method of production, chemical and electrolytic extraction, give an abundant supply, free of gross bacteriologic contamination, at nominal cost.

Preparation and sterilization of the solution is readily accomplished, but certain essentials must be observed, i.e., neutralization; addition of electrolytes; and testing for (a) viscosity; (b) hemolysis of red blood cells; (c) sedimentation of red blood cells; and (d) precipitation of fibrin.

The preliminary experimental work indicates that pectin is nonantigenic and nontoxic. It is retained in the body for a short period and then eliminated rapidly. There appears to be no cumulative effect in using the solutions described. Liver function as measured by the fractional bromsulphthalein test; and fibrinogen shows slight depression only with massive doses. In the 12 experiments on shock and hemorrhage, prompt and adequate response as

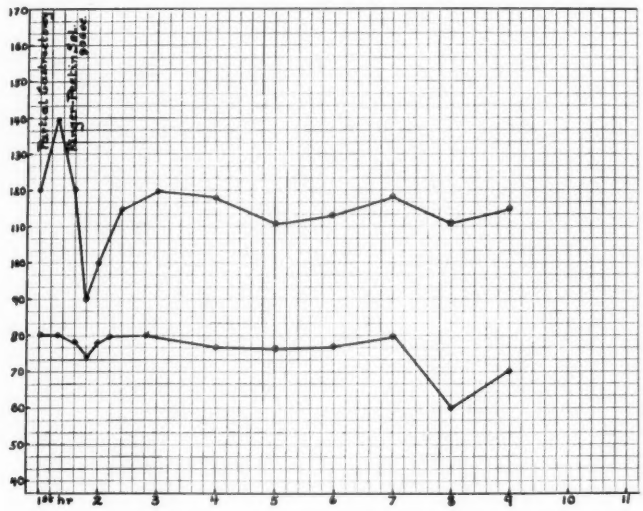

FIG. 7.—Case 3: C. V. No. 271727. White, female, age 56. Gastric ulcer with continuous symptoms for five years. Height 5′2″, weight 134¾ lbs. Operation July 3, 1941—Partial gastric resection. Preoperative blood pressure 88/64, hemoglobin 13.5 Gms. Received 950 cc. of 1 per cent pectin during the operation rather than the customary transfusion of whole blood. The blood pressure was maintained well above the preoperative level. Postoperative course was uneventful.

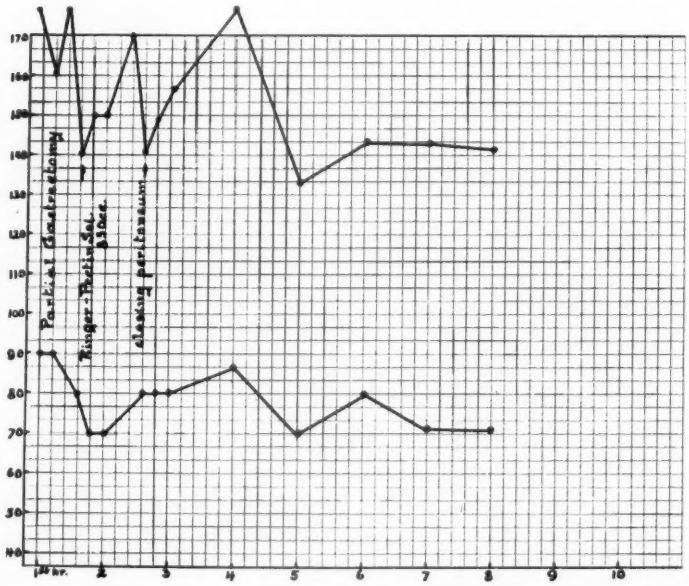

FIG. 8.—Case 4: J. M. No. 186791. White, male, age 66. Duodenal ulcer for past 15 years. 5′6″ tall, weight 140 lbs. Present studies show marked gastric retention and gallstones. On 7/3/41 had cholecystectomy, appendicectomy and posterior gastro-enterostomy. Admission blood pressure 120/70. Postoperative course uneventful. Anesthetic cyclopropane and ethylene (preoperative Hb. 15 Gm.). Received 900 cc. of 1% pectin during the course of the operation instead of the usual blood transfusion. Blood pressure levels were sustained at satisfactory levels.

measured by blood pressure graphs and the general condition of the animals was obtained in all.

The preliminary clinical application shows the patient (Case 1, Fig. 5) not in shock, with a moderate elevation of blood pressure after 600 cc. of 1 per cent buffered pectin solution. The bleeding time, coagulation time, and liver function were not altered. The mastectomy patient (Case 2, Fig. 6) in shock received a small injection of 450 cc. of the 1 per cent solution but the condition improved steadily over a three-hour period. The two patients receiving injections instead of the usual transfusions during partial gastrectomy operations (Cases 3 and 4, Figs. 7 and 8) maintained satisfactory blood pressure levels throughout. Three additional operative cases and one normal individual have received pectin intravenously without reaction or untoward results. In the operative cases, especial attention was paid to the bleeding time in the tissues of the operative wound but no variation from normal could be observed.

SUMMARY

(1) The intravenous use of pectin solution as a blood substitute in shock is proposed.

(2) One-half per cent of pure pectin solution has about the same viscosity and osmotic pressure as whole blood.

(3) Pectin has a high molecular weight, is nonantigenic and nontoxic.

(4) The source, method of manufacture, and the ease of preparing and sterilizing stable buffered solutions make pectin readily available.

(5) Preliminary experimental and clinical application indicate that pectin solutions are valuable in the management of shock.

(6) There is temporary retention of pectin in the blood and in the liver but excretion of the unchanged material in the urine is rapid.

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CANCER OF THE LIP*

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PART I

CANCER OF THE LIP is the most frequent but not the most fatal malignant neoplasm of the oral cavity. Unlike other intra-oral cancers, it can always be diagnosed early, and, except when a lesion is neglected and permitted to progress to advanced and complicated stages, the treatment, if intelligently conceived, is less hazardous and less difficult, technically, than that of most other serious forms of malignant growth.

The present report is based upon an intensive analysis of 375 consecutive cases of lip cancer, all histologically proved, admitted during the seven-year period, 1928 to 1934, and includes all patients with cancer of the lip who applied to our clinic during that period, without exclusion of any because of an advanced stage of the disease. Of the entire group, 99 patients (26 per cent) had received previous treatment by one of the accepted methods (surgery, radium, roentgenotherapy, endothermy, or combinations of them) and were admitted to our clinic with residual or recurrent disease. The treatment methods described are those which have been evolved at the Memorial Hospital during the past 25 years, beginning with the original radium technics of Janeway[26] and Quick.[46]

Definition.—Properly speaking, cancer of the lip is a mucous membrane tumor both anatomically and clinically, and, therefore, the term should be limited to those lesions which arise in the vermilion border or in the mucocutaneous junction of the lips. Basal cell carcinomas (which never arise in mucous membrane) and all other growths which develop on the skin apart from the vermilion border of the lips should not be included in this classification, but should be grouped with other cancers of the skin of the face.

ETIOLOGY

General Incidence.—According to the admission records of the Memorial Hospital, cancer of the lip comprises about 30 per cent of all malignant tumors of the oral cavity proper, about 20 per cent of all cancer of the upper respiratory and alimentary tracts, and about 4 per cent of all admissions for cancer. The latter figure is twice that reported by Widmann[64] (2 per cent) from the Philadelphia General Hospital, and by Stewart[56] from the Steiner

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Clinic. According to statistics furnished us by the Bureau of Records of New York City (1937),* cancer of the lip, despite its relatively high incidence, causes only 0.3 per cent of all cancer deaths, or one-fourth as many as the equally frequent cancer of the tongue (1.2 per cent of all cancer deaths).

Age and Sex.—In the series herein reported, the oldest patient was aged 88, the youngest aged 28, and the mean age for the entire group was 56 years. The average age as reported by other investigators varies between 52[18] and 65.[65] The majority (67 per cent) of our cases occurred between the ages of 50 and 69, with about 40 per cent after the age of 60.

In our clinic, the disease is limited almost entirely to males (98 per cent in the present series). Other investigators[24, 43, 55, 57, 41] have reported a female incidence ranging from 1 to 16 per cent. The reports from the Scandinavian countries[1, 2] indicate that cancer of the lip is more common among women there than it is in this country. Ahlbom,[1] in commenting upon this relatively high female incidence, suggests that it may be due to mucous membrane changes associated with achlorhydric anemia and the Plummer-Vinson syndrome which are so common among women in Sweden.

Race.—Cancer of the lip (like cancer of the skin) is more frequent in the white than in the colored race, probably for the reason that highly pigmented skins and mucous membranes are less subject to chronic irritation from physical sources (sunshine, weather, chemical irritants, *etc.*). In the present series, all were of the white race. It is obvious, however, that this comparative regional immunity to lip cancer does not extend to the rest of the oral cavity, for it is well known that the Negro is particularly subject to lingual and buccal cancer arising on the basis of chronic syphilis. While the records of the Memorial Hospital contain a few cases of lip cancer in mulattoes, so far as we know, none has occurred in a full-blooded Negro. Hall[24] does not state whether or not the three Negroes reported in his series were full-blooded. According to Brewer,[7] the disease is not uncommon in Negro women who are pipe smokers.

Position of the Growth.—The disease occurs almost exclusively on the lower lip (93 per cent). In the present series, only 6 per cent of the lesions occurred on the upper lip and about 1 per cent directly in one of the labial commissures. Some authors report much larger relative percentages of cancer of the upper lip, as for instance Forssel[23] 25 per cent, and Widmann[64] 10 per cent. Such figures are difficult to explain unless one assumes that these observers included basal cell carcinomas of the skin apart from the vermilion border of the upper lip, which we believe should properly be placed in the general group of skin cancers.

It may be of passing interest to note the percentage distribution of lip cancer as regards the right and left sides, excluding, of course, those growths arising directly in the midline. In the present series, 56 per cent occurred on the left. Simmons[55] found 53 per cent of 108 cases on the left. In most reports this factor is not mentioned. In this connection, we were at first

* Personal communication from Thomas J. Duffield, Registrar of Records, New York, N. Y.

impressed by the additional fact that in a recent analysis of over 500 cases of tongue cancer at the Memorial Hospital, there was, likewise, a greater incidence (57 per cent) on the left. Superficially considered, these several data might seem sufficiently consistent to suggest an actual left-sided preponderance of intra-oral cancer, but when the older literature is investigated, it is found that about an equal number of investigators have reported a right-sided trend in lip cancer (Janowsky,[27] Rowntree,[50] Wörner,[66] and Loos[33]). Kennedy,[30] dividing the lip into three areas, found an equal incidence in the right and left thirds. Since it is well-known that in the case of alternates the laws of chance favor moderate one-sided shifts rather than exactly equal distributions, especially when the number of cases is small, the cautious observer must conclude that such irregularities as those mentioned above are purely coincidental.

Causative Factors.—In lip cancer, the entire labial mucous membrane usually shows some evidence of chronic irritation. Such evidence may appear in the form of a scaly cheilitis, excessive dryness, multiple keratoses, leukoplakia, epidermization, or a tendency toward vertical folding and fissuring.

In almost 20 per cent of our series, there was a definite history of frequent "fever blisters," chapped lips, fissures, excessive sunburn, or an habitual tendency to bite or chew the lips. It is rather difficult, however, to assay the relative etiologic significance of these and of the several other chronic irritants and their resultant mucous membrane changes, which will be described below.

Climate, Exposure to Weather, and Occupation.—It has been repeatedly noted in the literature that cancer of the lip (as well as of the exposed skin of the face and hands) is common in outdoor workers such as farmers, sailors, ranchers, *etc.*, who undergo unusual exposure to the dry, irritating effects of the wind and sun. By virtue of its position, the lower lip (especially in prognathism) is more subject to such effects than is the upper lip, which may be additionally protected by a mustache. It is well-known that exposure to cold and salt spray produces keratoses of the exposed skin and lips in sailors. Cowan[13] has recently discussed the high incidence of facial skin and lip cancer in the general population in the mountainous plateaus of Utah. The climate in these high altitudes combines to an unusual degree such factors as dryness of air, alkali dust, uninterrupted sunshine during the daylight hours, and a high component of actinic radiation through an atmosphere which is usually clear of clouds and smoke.

In the present series of patients, drawn mainly from an urban population, the percentages of outdoor and indoor workers were about equal. It is probable, however, that no special significance can be attached to these figures, since the normal occupational distribution in a large metropolitan center is impossible of accurate determination. Lane-Claypon,[32] in a series of about 1,000 cases collected from the literature, reports that over 80 per cent occurred among outdoor workers, but she gives no information as to the occupational distribution in the population samples, except in the report of 176 cases by Janowsky,[27] who found the proportion of outdoor workers in his lip cancer

group to be about the same as in the general population from which his cases were drawn. Ahlbom[1] states that 90 per cent of his patients were outdoor workers, but he fails to give the normal occupational distribution of the general Swedish population.

It has seemed significant in a few individual cases in our series that a carpenter or cobbler has given a history of habitually holding nails in the mouth, a practice which the patient himself has quite reasonably believed to be the cause of his cancer.

Tobacco.—That the smoking of tobacco in itself is directly responsible for the development of intra-oral cancer, is an old belief which, though undoubtedly founded in fact, nevertheless, is not well-supported by any statistical evidence thus far adduced. We refer here to the general effects of tobacco and not to those relatively rare instances in which cancer may arise on the lip at a point where the transmitted heat and the rough surface of a clay pipestem combine as chronic irritants in so-called "pipe-smoker's" cancer, or to those instances in which cancer arises in the leukoplakic tongue of an excessively heavy smoker. In about 11 per cent of our series, the patients gave histories of irritation from a pipestem or a tendency of cigarettes to stick to the lip at or near the site of a subsequently developing growth. Although in some of these instances a causal relationship is probable, we believe that, on the whole, no greater credence should be given to such statements by patients than to the average alleged association between a trauma and a subsequently developing cancer. At any rate, it is obviously not so much the tobacco *per se* which is responsible in these cases, but rather the excessive indulgence and the mechanical contrivance used.

When an attempt is made to prove such an effect of tobacco statistically, the calculations, in our opinion, always remain inconclusive. In our series of lip cancers, over 70 per cent of the patients admitted the use of tobacco in some form, and similar one-sided figures have been employed frequently to prove a direct causal relationship, disregarding the fact that normal healthy adults are addicted in about the same degree. To investigate this subject thoroughly, one would be faced with such difficulties as evaluating the relative effects of various degrees of indulgence, the influence of recent or remote past addiction, and the several forms of the habit.

We suspect that the emphasis often placed upon the cancerigenic influence of the tobacco habit is to some extent influenced by the ubiquitous moralistic propaganda against the "filthy weed." Once raised, the question has been discussed to a far greater extent than its importance merits in attempts at honest appraisal by the more open-minded and tolerant. Although admittedly an important factor in a few individual instances, the production of cancer is certainly one of the less harmful effects of tobacco. One often encounters similar Puritanic overemphasis with regard to the rôle of alcohol in the causation of various diseases.

Syphilis.—In the present series, the incidence of syphilis, as shown by positive Wassermann tests, was about 10 per cent. This figure is almost twice the general incidence, namely, 6 per cent, in white males of a correspond-

ing age (56 years), according to Usilton.[60] The disparity of 4 per cent between these two figures indicates the relatively moderate influence of syphilis in the etiology of cancer of the lip. The published percentages of syphilitics among lip cancer patients vary from 2 per cent[29] to 20 per cent.[53] The degenerative mucous membrane changes produced by chronic syphilis (chronic glossitis, leukoplakia, *etc.*) are much more pronounced in the tongue and mucosa of the cheeks than in the lips, and it is obvious, therefore, that syphilis should be less prominent in the etiology of cancer of the lip than in growths in these other intra-oral sites.

Defects in Dental and Oral Hygiene.—The lips are also less subject to chronic irritation from sharp or worn teeth than are the tongue and the buccal mucosa, but occasionally a causal relationship is suggested by one or two very sharp teeth in the lower jaw opposite the growth. In the present series, however, direct dental irritation could be demonstrated but rarely, and 13 per cent of the patients were edentulous. In only about 5 per cent was it noted that the dental hygiene was good, but in interpreting this figure one must consider that the great majority were clinic patients in whom, as a class, good dental hygiene is rare.

Leukoplakia.—In the present series, no careful routine survey was made to discover very early or slight evidences of leukoplakia, but in about 28 per cent of the patients, well-established, easily demonstrable leukoplakia was noted on the lips, the tongue, or the cheeks. The presence of some degree of leukoplakia in the oral mucous membranes after middle age cannot be considered particularly abnormal since, in the majority of cases, it represents simply a response of the mucous membrane to mild chronic irritation and, as such, is a part of the natural aging process comparable to the almost universal mild senile changes, including keratosis of the skin, which begin at, or soon after, middle age.

In a recent investigation carried out at the Memorial Hospital, 100 males and 100 females, all over 40 years of age, and without any intra-oral complaint, were carefully examined for intra-oral leukoplakia. Some degree of leukoplakia was found in 50 per cent of the males and in 10 per cent of the females, so slight in many instances, however, that the condition would usually be overlooked in the average examination. In 12 per cent of the males, the lesions were well-established and easily recognizable even on cursory inspection. Some idea of the etiologic significance of leukoplakia in lip cancer can be obtained by comparing the incidence of well-established leukoplakia in our series of lip cancers (28 per cent) with the above-mentioned 12 per cent in the otherwise normal adult male population.

Acute or Chronic Trauma.—In any large series of cancer cases, there are, invariably, some patients who attribute the beginning of the growth to an acute trauma. In the present series the following were alleged: A cut with a razor, an abrasion by a corn stalk, an injury with a lollypop stick, a blow with the fist, severe accidental biting of the lip, and a scratch by a fish bone. It is our opinion that in most such instances the injuries were purely coinci-

dental, since we doubt the capacity of a single acute trauma to produce cancer in an otherwise normal mucous membrane.

Contact Implantation of Cancer.—It has been believed by many that cancer can be transplanted by contact from a primary lesion to overlying mucous membrane. Instances of this character have been reported as occurring from one lip to the other, from one oral mucous membrane to another, from one wall of the rectum to the opposite, *etc.* To the surgeon who has performed tissue transplants, such as skin, fascial, tendon, and other such grafts, under necessarily aseptic technic, the possibility of the accidental grafting of an infected surface cancer to an unbroken opposing mucous membrane appears exceedingly remote. It seems to us that the reported instances[12] of contact implantation from one lip to the other are undoubtedly cases of multiple cancer.

HISTOPATHOLOGY

Histologic examination will reveal some form of squamous carcinoma in practically all lip cancers. About half of our cases were squamous carcinoma Grade II, and one-third were Grade I, with Grades III and IV making up less than 2 per cent. In our opinion, the reported instances of basal cell carcinoma occurring on the lip should not properly be included in this group, since, as previously mentioned, they obviously arise in the skin apart from the vermilion border and, therefore, should be classified with other facial skin cancers. To include these basal cell growths tends only to confuse and obscure the true clinical significance of the term *cancer of the lip.* Adenocarcinoma arising in the minor salivary and mucous glands of the lip occurs occasionally, but there was none in the present series. Spindle cell carcinoma was found in three cases. This rare and highly malignant tumor usually arises in scar tissues, in most cases either in the mucous membrane of the lip or in the adjacent skin. One of us (H. M.) and Stewart[37] have recently reported eight cases of this tumor, four of which occurred in the region of the lips.

SYMPTOMS, MORBID ANATOMY AND CLINICAL COURSE

In its early and moderately advanced stages, lip cancer is a relatively benign disease, and the first and almost the only symptom is the presence of the primary lesion. Even in the advanced stages the growth on the lip itself disturbs no vital function, and for this reason, in most of the uncontrolled cases, death is due to dissemination of the disease either to the cervical nodes or, less often, to the viscera. If untreated, the clinical course is usually slow and of long duration, and the patients, as a rule, remain in fairly good general condition until the disease is far advanced. In this series, the average length of life of the unsuccessfully treated patients was about 43 months after the onset of symptoms.

The Primary Lesion.—Frank ulceration of the growth accompanied by a definite alteration in the surface contour of the lip is seldom a prominent early finding, but it practically always occurs when the lesion has reached a size of 5–7 mm. In some instances, the first objective symptom is a firmly attached, superficial crust or scale rather than a true ulcer (Fig. 1). Bleeding occurs

A. B.

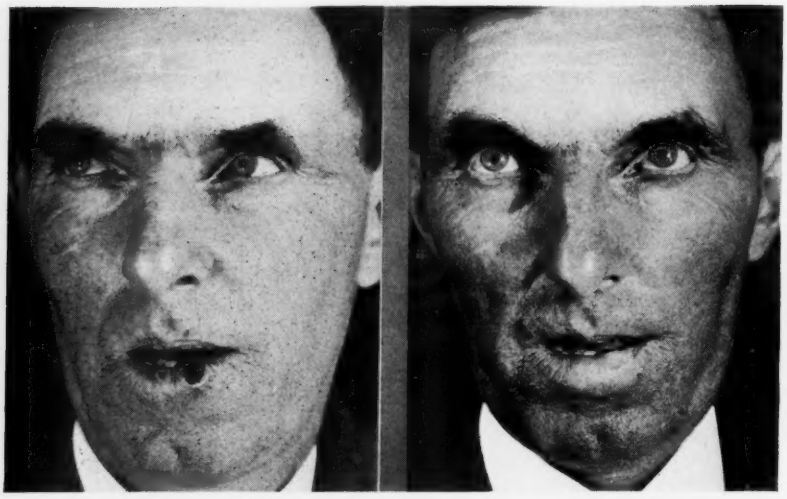

FIG. 1.—Early cancer of the lip. Most patients with lip cancer seek medical advice when the lesions are between 1 and 1.5 cm. in diameter. At this stage, the lesion commonly consists of a flat, slightly raised, painless and nontender ulcer of about ten to 12 months' duration. The edges tend to be raised and rolled. At this stage, metastasis has taken place in about 10 per cent of cases, as judged on the basis of the clinical presence of involved nodes on admission, or their later development after control of the primary lesion. (A) Before treatment. (B) Healed condition after roentgenotherapy, showing minimum of scarring and cosmetic deformity.

A. B.

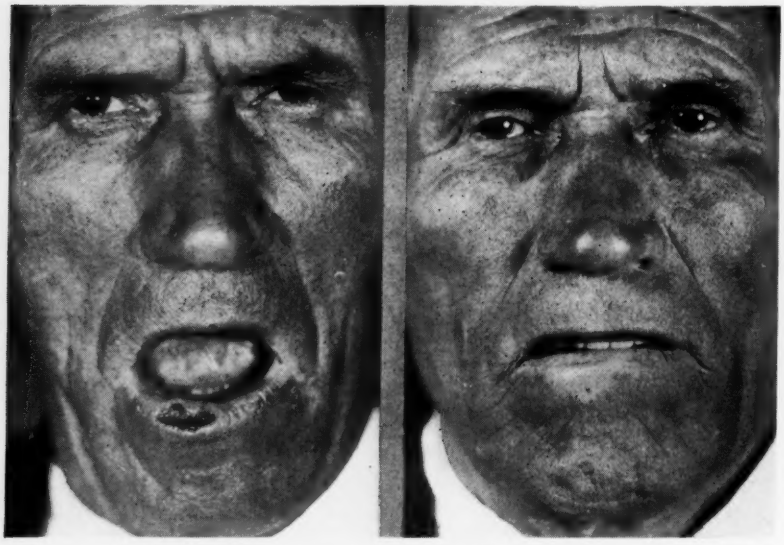

FIG. 2.—Moderately advanced cancer of the lip. When lower lip cancer approaches 2 cm. in diameter, there is usually marked ulceration of the surface. The growth may fungate, or there may be an excavated ulcer with indurated edges and infiltration to a depth of 8–10 Mm. Metastasis has taken place in about 15 per cent of the cases, as determined by the clinical presence of metastatic nodes on admission or their later development after control of the primary lesion. (A) Before treatment. (B) Healed condition after treatment by combination of external and interstitial radiation.

when this crust or scale is detached. There is usually palpable induration well beyond the borders of any visible lesion. Pain and tenderness are characteristically absent. The patient is likely to regard an early lip cancer as a

FIG. 3.—Advanced cancer of the lip treated by surgical excision and plastic closure. The disease in this case was of six years' duration and had invaded practically the entire horizontal diameter of the lip, extending deeply into the free border and causing marked ectropion. No metastases were demonstrable clinically. This patient has remained well and free of disease for six years.

A. B. C.

FIG. 4.—Advanced cancer of the lip of four years' standing, without clinically demonstrable cervical metastases. In this clinical form of the disease (A), the growth invades the lip deeply, without marked erosion or ulceration. (B) Immediate postoperative condition. The growth has been widely excised and the defect closed by advancing the lateral edges and, in addition, by bringing down an Estlander's flap from the upper lip. (C) Final healed condition. The patient has remained free of disease for five years.

"cold sore" or a "chapped lip," and usually fails to seek medical advice until the growth has reached a diameter of about 1 cm. In the present series, of those cases in which the exact size of the lesion was stated (329 cases), only about 39 per cent of the primary lesions were 1 cm. or less in diameter, 33

per cent 1.1 and 2 cm., 13 per cent between 2.1 and 3 cm., and 15 per cent over 3 cm. In 15 cases (4 per cent), practically the entire lower lip was involved when the patients applied to our clinic.

When the growth becomes more advanced, it usually presents a flat, slightly raised, coarsely granular and indurated ulcer which fixes and renders inelastic the volume it occupies (Fig. 2). Sometimes the edge of the ulcer becomes raised, rolled, and slightly undermined. After reaching this stage, the growths may be classified into two general groups: (1) The less malignant, which fungate from the surface without deep infiltration or erosion; and (2) the more malignant, which tend to invade deeply and erode the substance of the lip. Fungating tumors may reach a size of 6–7 cm. with little or no local destruction of tissue. On the other hand, bulky tumors may infiltrate deeply with only a moderate degree of ulceration and erosion (Figs. 3 and 4). In still other instances, there is wide ulceration and destruction of the lip without deep invasion. Various other combinations of these clinical forms may occur. After a period of one to two years, the growth often extends into the cheeks past the commissures into the gingivobuccal gutters, onto the lower alveolus, and even into the floor of the mouth. The progress of the disease is sometimes so slow that after two or three years the growth may be only 3–4 cm. in diameter without evidence of cervical metastases.

The average duration of symptoms before admission in the present series, from patients' statements, was about 15 months, which is an indication of the slow and relatively benign course of this tumor. The shortest duration was two weeks, as stated by a patient whose lesion was 2 cm. in diameter on admission, a size which indicated a much longer duration. The longest alleged durations were 15 and 17 years, respectively; in both of these cases the patients gave histories which, though inadmissible without further proof, were nevertheless difficult to refute.

Cancer of the Upper Lip.—This anatomic form of the disease is relatively uncommon. In our series there were 21 cases (6 per cent). As has been previously stated, the upper lip is less subject to chronic irritation than the lower, and malignant growths of the upper lip follow the general rule that spontaneous cancer is more malignant than that which arises on the basis of chronic irritation. These upper lip cancers usually ulcerate soon after they arise, grow rapidly, and metastasize early to the preauricular and/or infraparotid lymph nodes, where the growth soon perforates the node capsule and infiltrates widely. In our 21 cases, metastases eventually occurred in ten (48 per cent), as compared to 30 per cent in the lower lip. Seven of the patients, with upper lip cancers which metastasized, eventually died (33 per cent). The prognosis of cancer of the upper lip is definitely worse (41 per cent five-year cures in the determinate group) than cancer of the lower lip, and the clinical course from the onset of symptoms in uncontrolled cases is relatively short (21 months in our fatal cases as compared to 43 months in lower lip cancer).

METASTASES

As a rule, metastasis in lip cancer occurs later in the course of the disease than in cancer of the tongue, floor of the mouth, or tonsil. In the present series, despite an average duration of the primary lesion of 15 months, the incidence of palpable metastases on admission was only 29 per cent. After admission, about 8 per cent subsequently developed metastases, so that, finally, a total of about 37 per cent presented metastases some time during the course of the disease. In this series, therefore, 63 per cent of the cases had no metastases at any time—indicative of the factor which, more than any other, is responsible for the relatively high cure-rate in lip cancer. When the primary lesion was under 1 cm. in diameter, the incidence of palpably metastatic nodes on admission was only 3 per cent. When the diameter was less than 2 cm., the incidence increased to about 8 per cent.

Except when the disease arises on the upper lip, the position of the first node involved and the later progress of cervical metastases tends to be rather orderly; that is, the nodes most often involved are the submaxillary (over 50 per cent of the cases which metastasize) or submental (about 8 per cent) of the corresponding side, with orderly progression from these areas to the upper deep cervical and later to the middle and lower deep cervical regions. These orderly tendencies depend not only upon the well-differentiated and rather uniform histology of the growths in this area, but also on the anatomy of the lymphatics of the lip. Crossed or bilateral metastases may develop, especially when the primary lesion is near to or crosses the midline of the lip. In the present series, there were bilateral submaxillary metastases in about 11 per cent of the lesions which metastasized.

TABLE I

INCIDENCE OF CERVICAL METASTASES IN LIP CANCER
According to Size of Primary Lesion

Size of Lesion	No. of Cases	Present on Admission	Developed After Admission	Total Developed During Course	None at Any Time
Under 1 cm.	33	1 (3%)	1 (3%)	2 (6%)	31 (94%)
1 to 1.9 cm.	118	10 (8%)	11 (9%)	21 (17%)	97 (83%)
2 to 2.9 cm.	49	11 (22%)	5 (10%)	16 (32%)	33 (68%)
3 cm. and over	60	29 (48%)	8 (13%)	37 (61%)	23 (39%)
Entire lip	5	2 (40%)	0	2 (40%)	3 (60%)
Not stated	48	37 (77%)	2 (4%)	39 (81%)	9 (19%)
Total	313	90 (29%)	27 (8%)	117 (37%)	196 (63%)

The incidence of cervical metastases in relation to the size of the primary lesion on the lip is given in Table I. It is interesting to note that metastases occasionally occur very early when the lesions are 1 cm. or less in diameter on admission (3 per cent). In our series, the incidence markedly increased with the size of the lesion up to 2 cm. Between 2 and 3 cm. diameters, the incidence of metastases on admission more than doubled, and again increased by about 50 per cent in lesions over 3 cm. Following control of the primary lesion, the subsequent incidence of metastases increases only slightly as the size of the lesion increases, and it would appear that if a growth has reached

a size of more than 3 cm. without metastasizing, the chances of subsequent development of metastases is very slight (13 per cent).

Once metastases from the lip have developed, their further dissemination tends to be somewhat less rapid than in many other forms of intra-oral cancer. If not controlled, the growth finally perforates the capsules of the nodes, infiltrates the surrounding tissues, and becomes fixed to the mandible or other deep structures and eventually to the skin. Such nodes often suppurate, perforate the skin, and drain on the surface. Until the advanced stages, however, metastasis from lip cancer tends to remain above the level of the clavicle, although general dissemination eventually occurs more frequently than is usually realized. In a survey of the autopsy records of the Memorial Hospital, it was found that in 14 patients dead of lip cancer, visceral metastases had occurred in four (29 per cent). Dissemination below the clavicle should occur even more often from cancer of the tongue or the pharynx where the relative proportion of anaplastic growths is higher. Autopsies on 50 patients dead of tongue cancer, at the Memorial Hospital, revealed distant metastases in 20 (40 per cent).

In a survey of the literature, we have been unable to find other conclusive data on the subject of visceral metastases in lip cancer. Burke[9] and Price[45] report that in four and eight autopsies, respectively, on patients dead of lip cancer, there were no metastases below the level of the clavicle. Although these findings differ from ours, the fact remains that the total number of autopsies in all these series is not great. Our small series of lip cancer autopsies may have shown an abnormally large percentage of disseminated metastases, and it may be a coincidence only that the cases of Burke and Price showed none. On totaling these three series (26 cases), however, the incidence is still about 15 per cent. It is more difficult to explain and to accept the validity of the conclusions drawn by Crile,[14] who reports that Hitchings, in a collected series of 4,500 patients dead of cancer of the head and neck (not lip cancer alone), found that less than 1 per cent showed distant metastases. One who has closely followed the terminal stages of the various forms of intra-oral cancer, and has seen autopsies in large numbers of these cases, cannot help wondering what actually caused death in Hitchings' collected series, if less than 1 per cent had visceral metastases. Is it possible that many of them were postoperative deaths following neck dissection or excision of the primary lesion? Crile does not state whether the anatomic diagnoses with reference to generalized metastasis were confirmed by postmortem examinations, but in the absence of such a statement it seems probable that most of the final diagnoses were made on clinical observations alone. If a large percentage of Hitchings' series were postoperative deaths, then it is obvious that the cases must have been operable and fairly early, and that for this reason alone dissemination of the disease below the level of the clavicle would have been rare.

Anatomy of the Lymphatics of the Lip.—According to Most,[40] Sassier,[52] and Rouvière,[49] the lymphatics of the lower lip arise in the vermilion border

as a fine capillary network (Fig. 5). This network combines to form several main collecting trunks which run downward over the chin into the submental and submaxillary regions. In the midline, there are fairly numerous anastomoses which account for the rather frequent crossed or bilateral metastases

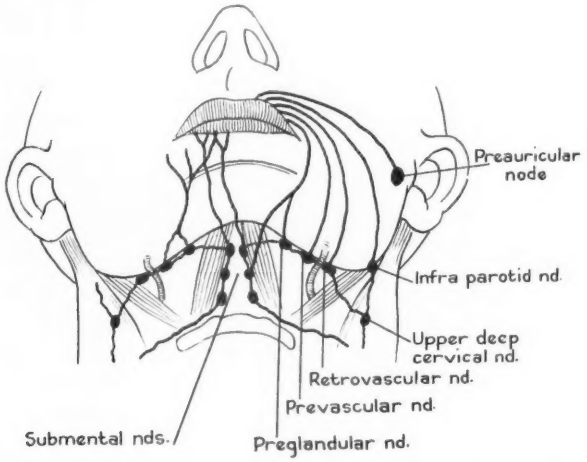

FIG. 5.—Anatomy of the lymphatics of the lip. (After Rouviere.[49]) The lymphatics of the lower lip drain into the submental, submaxillary and, eventually, into the upper deep cervical lymph nodes. Metastases may occur on the side opposite the lesion by anastomosis across the midline. The lymphatics of the upper lip drain into the preauricular, the infraparotid, the submaxillary, or the submental nodes.

from growths which are near to or cross the midline. All of the lymphatics of the lower lip drain into the submaxillary and submental lymph nodes. Of the latter node groups, the most important is the submaxillary, which lies under the lower edge of the mandible at the crossing of the facial vessels and consists of the prevascular and retrovascular nodes, respectively. The submental region contains a group of several nodes. Both the submaxillary and submental groups drain into the upper and sometimes into the middle nodes of the jugular chain.

The lymphatics of the upper lip drain into four node groups, namely, the preauricular, the infraparotid, the submaxillary, and the submental. In our experience, the first metastases from the upper lip occur most often in either the preauricular or infraparotid nodes and then progess rapidly to the upper and middle nodes of the jugular chain.

DIAGNOSIS

Although the physician as well as the patient may frequently procrastinate, one seldom finds such serious errors in the diagnosis of lip tumors as are made in lingual cancer, where growths are often treated for long periods under the mistaken diagnosis of syphilis or dental trauma. Except for those lesions which are discussed below, the lip is not particularly susceptible to any disease likely to be mistaken for cancer, or *vice versa*. There is no portion of the anatomy which is under closer observation by the patient and

his friends than the lips, and no abnormality in this region can long escape attention. Delay in diagnosis and treatment (averaging about 15 months in our series) is due mainly to the absence of distressing subjective symptoms. In 10 per cent of the present series, the first physician consulted had prescribed topical applications of various sorts (usually salves) for periods of several weeks or months. Such lack of diagnostic acuity can be ascribed mainly to indolence on the part of a physician who may hesitate to make any positive diagnosis which would entail a more definite recommendation for active and aggressive treatment.

Although it may seem heretical from the standpoint of cancer education to say so, our figures indicate that a moderate delay in diagnosing lip cancer does not affect the prognosis, for in the present series the cure-rate, in lesions up to 1 cm. in diameter (moderately advanced), was 100 per cent. The main advantage of early diagnosis is the superior cosmetic result in smaller lesions following treatment by either radiation or surgery.

Biopsy is essential for purposes of record in lip cancer as in all other forms of this disease. In small lesions (3–4 mm. in diameter), the removal of a biopsy specimen before treatment is usually not practicable, and if treated by radiation these early cases, lacking histologic confirmation of the diagnosis, should not be included for statistical purposes as cured cancer. If treated surgically, the excised tissue is always available for histologic examination. In lesions over 3–4 mm., a small wedge should be taken in all cases before treatment by radiation; when treated surgically, the question of preoperative biopsy in these lesions is the responsibility of the surgeon. In some cases, the clinical diagnosis may be so obvious as to render biopsy unnecessary, but to widely excise a tumor of the lip under a mistaken clinical diagnosis of cancer should be considered a reproach to the operator.

Papilloma.—The lower lip, like all other oral mucous membranes, occasionally gives rise to papilloma. Although such benign lesions usually present the warty, fungating appearance typical of papillomas elsewhere, there may occasionally be frank ulceration and some erosion. In typical lesions, the diagnosis may be suspected from the clinical appearance but should always be confirmed by biopsy (repeated if necessary), the specimen being taken from the edge and base rather than from the apex or the surface of the growth. From the practical standpoint alone, and aside from purposes of record, accurate diagnosis in these cases is of minor importance, since the treatment for cancer and papilloma is the same.

Keratoses of the Lip.—In persons who spend much time out of doors, sunburn, chapping, and fissuring of the lower lip frequently occur, and the mucous membrane undergoes definite changes resulting eventually in epidermization and leukoplakia. Keratoses often occur and may be single or multiple and cover large areas of the lower lip. In persistent cases of this character, the diagnosis as to the presence of early cancer may be not only difficult but impossible. When such suspicious precancerous lesions are widespread, radical treatment, either surgical or radiologic, to the entire lower

lip is rarely justified. Even when cancer eventually develops in these doubtful cases, the clinical course is relatively slow, and, therefore, one may withhold aggressive treatment until there is definite clinical evidence of cancer in the form of a progressive lesion persisting at one or more points for periods of several weeks or months. While under such observation, the lip should be protected from further exposure to sun and weathering and treated by the application of such protective ointments as cocoa butter. Once decided upon, the treatment of doubtful keratoses, whether by radiation or surgery, should be just as thorough as when the diagnosis of cancer is certain.

Herpes.—An apprehensive patient frequently seeks medical advice because of herpes, a lesion which may persist through its various stages for several weeks before healing. The history of its sudden appearance with pain is one of the most valuable points in differential diagnosis.

Syphilis.—Primary chancre and secondary syphilids may occur on the lower lip, and their chronicity and the relative absence of pain and tenderness may raise some doubt as to the possibility of cancer. Since any syphilitic lesion of the lip is extremely rare, this question of differential diagnosis is of little practical import. Apparently, this fact is not universally appreciated by the medical profession, for in seven cases of our present series (2 per cent) antiluetic treatment had been given over periods of several weeks to months before the correct diagnosis of cancer of the lip was suspected. Simmons[55] has reported cancer developing in the scar of a chancre which had been present two years previously.

Other benign lesions such as tuberculosis, simple ulcers, retention cysts, muscle xanthoma, and hemangioma are either rare or present no problem in differential diagnosis.

Diagnosis of Cervical Metastatic Cancer.—An essential finding for the clinical diagnosis of cervical metastatic cancer is the palpable presence of enlarged lymph nodes, without which it must be assumed for all practical purposes that metastases are absent. The fact that cervical lymph nodes are palpable, however, does not necessarily mean that they have been invaded by cancer, nor does it signify even that they are enlarged. A careful search will reveal palpable cervical lymph nodes in about 50 per cent of all normal persons (at the lower edge of the mandible at the crossing of the facial vessels, in the submental regions, or in the carotid bulb area), and, therefore, case histories which state that "nodes are not palpable" are confusing since the reader is left uncertain as to whether the examiner mistakenly considered that all palpable nodes were metastatic or otherwise diseased.

(In many published reports on intra-oral cancer, cervical "glands" are spoken of as being "present," "absent," "palpable," "enlarged," "soft," "hard," *etc.*, and when no confirmatory histologic data are given the helplessly confused reader is left to interpret the clinical significance of such vague observations and terminology. The fault here is twofold. In the first place, the examiner has evaded the responsibility of stating whether or not he believes metastases to be present. If the examiner expresses no definite opinion, how can the reader be expected to form one on such equivocal evidence? In the second place,

the term "gland" or "cervical gland" is inexplicit and confusing. While we concede that the term "lymph gland" has the sanction of anatomists, it should be remembered nevertheless that the neck contains many glands beside those in the lymphatic system; namely, the parotid salivary, the submaxillary salivary, the thyroid, and the parathyroid. It is unfortunate, therefore, that the term "gland" should ever have been applied to cervical lymph nodes, since such a designation is too inclusive and apparently has led many physicians to believe that metastasis commonly takes place in any or all of these various glands. This error is often a cause of anxiety to the inexperienced who discover the presence of palpable but otherwise normal thyroid and submaxillary or parotid salivary glands. If the term "node" or "lymph node" were used instead of "gland" or "lymph gland," much of this confusion would be eliminated.)

Many writers infer that palpable lymph nodes must be either "metastatic" or "inflammatory," a conclusion which does not necessarily follow. In cases where there is marked intra-oral and dental sepsis or an infected cancer, sepsis, alone, may obviously be responsible for some enlargement of the cervical lymph nodes. In the absence of other symptoms or of abnormal enlargement, moderate bilateral and symmetric palpability of lymph nodes is presumptive evidence of their benign character. The unilateral or asymmetric enlargement of one or more nodes is always indicative of a serious pathologic process, and when accompanied by induration without tenderness this finding is one of the most valuable criteria in the diagnosis of metastatic cancer.

Accuracy in the clinical diagnosis of metastatic lymph nodes is achieved only by experience, and by repeatedly checking definite preoperative opinions against postoperative histologic examinations or aspiration biopsies. In clinics, where routine neck dissections are performed for both prophylactic and curative purposes, the accuracy of clinical diagnosis appears to be low (from the published reports,[20, 30, 58] 20–33 per cent) even in cases where the nodes are said to be "palpable." Taylor and Nathanson,[58] in reporting a collected series of lip cancer, state that out of 186 neck dissections, "palpable" nodes were histologically positive in only 17 per cent. Kennedy,[30] in a similar collected series of 64 patients, in whom "no nodes were felt," found that 14 per cent were positive when histologically examined. These authors were not themselves personally responsible for the accuracy of the diagnoses in these cases which were collected from general hospital admissions; the clinical descriptions were made by a number of observers—in many instances, probably by junior members of the house staff. These findings, therefore, should not be taken to represent more than the judgment of the average examining physician who may have little special interest in cancer. The decisions to operate and the operations themselves in the above-mentioned series were also divided among a number of surgeons. For these reasons, what appears to be such inaccuracy in diagnosis is probably not representative of the best effort of the surgeon who performs neck dissections. In any event, rather indifferent diagnostic skill must be expected when the treatment is the same (neck dissection) whether nodes are said to be "palpable," "not palpable," or otherwise. Especially where prophylactic

neck dissections are routine, the *tactus eruditus* necessary for reasonable accuracy in diagnosis is superfluous, and, therefore, is not likely to be developed. With regard to metastatic lymph nodes, if the term "palpable" were used only in its strict adjectival sense and lost all sanction as an expression of the clinical diagnosis, this fault would soon be remedied.

TREATMENT OF CANCER OF THE LIP

As is also true in most other intra-oral tumors, the treatment of cancer of the lip consists of two separate problems: (1) The care of the primary lesion; and (2) the cervical metastases.

The general plan of management should be based on a consideration of the special anatomic and clinical features of this form of the disease. Cancer of the lip can in most cases (at least 65 to 70 per cent) be diagnosed early and treated before metastasis has taken place. In evaluating treatment methods for the primary lesion, it is of significance that the lower lip is readily accessible to both surgery and radiation. Radiation methods may be employed in adequately heavy dosage with the neighboring normal tissues adequately shielded from undesirable reactions. Large portions or even the whole of the lower lip may be excised and replaced by plastic repair without great difficulty. For these reasons, either radiation or surgery can be employed with equally good chances of cure in the uncomplicated primary lesion. The selection of the treatment method in an individual case must, therefore, be made upon some basis other than the supposed superiority of one or the other method from the standpoint of cure alone—the most important considerations being the cosmetic result and the expediency of one particular method as regards its availability, the training and experience of the surgeon, the period of morbidity, and the general condition of the patient.

A survey of the literature will reveal that a number of methods with varying technics, both surgical and radiologic, have been used successfully for the treatment of the primary lesion in this disease. These methods include surgical excision, cautery excision, electrodesiccation, roentgenotherapy, surface and contact radium application, interstitial radon seeds and needles of radium and radon ([2, 20, 26, 29, 38, 42, 43]). Those who have had broad experience with these several methods will agree that none has any exclusive superiority over the others in all stages and clinical forms of the disease, either from the standpoint of cure or the functional and cosmetic result. The comparative merits of radiation and surgery in the treatment of cancer in general cannot be very convincingly proved by the end-results of either in cancer of the lip. It is significant that proponents of the exclusive use of one or the other of these methods commonly present the results obtained in the treatment of early lip cancer as proof of the merits of one particular method to the exclusion of the other for all malignant tumors. Cancer of the lip is the least malignant anatomic variety of intra-oral cancer, and except in the later stages the prognosis is reasonably good with any accepted method properly employed. In the advanced cases where unusual

difficulty is encountered, the fair-minded surgeon will gratefully and willingly employ all worth while methods in combination.

The time-honored method for the treatment of lip cancer is surgical removal in the form of a V-shaped wedge for smaller growths and of extensive plastic procedures for those more advanced. While capable of curing the local lesion in practically all early cases, if properly applied, these surgical procedures always produce cosmetic defects, the gravity of which depends on the extent of the excision. Since the lower lip is such an important structure from the cosmetic standpoint, radiation measures have long been preferred by many, especially in the earlier lesions. When judiciously employed, such treatment will produce a high percentage of cures with a minimum of deformity.

On the other hand, when a lesion is further advanced and when it has replaced or eroded a volume of 1.5 cm. or more of the lower lip, the treatment, even by radiation, may leave a tissue defect or a marked sclerosis. From the functional and cosmetic standpoints, these radiation sequelae in the advanced cases may be more undesirable than the deformity following surgical removal. Such remaining radiation defects often require plastic repair after healing, and in these, since a perfect cosmetic result is unattainable by any means, surgical excision in the beginning is often the more practical and expeditious method. Certain other widely infiltrating lesions are often best dealt with by combinations of radiation and surgery.

As has already been mentioned, the management of the cervical metastases presents a problem separate from that of the primary lesion. Considerable controversy exists as to whether prophylactic treatment, either radiation or surgery, should be used in the absence of clinically positive metastases. There is also a difference of opinion as to whether surgery or radiation is the more efficacious in the treatment of actual metastases. We believe that an unbiased consideration of these controversial questions will demonstrate that, as in most controversies, the truth lies between the extreme viewpoints. In the discussion which follows, we shall attempt to present a fair appraisal of the relative merits and specific advantages of radiation and surgery in the several clinical forms and stages of lip cancer.

The methods about to be described are those developed at the Memorial Hospital during the last 25 years, beginning with the radiation attempts in 1914 by the late H. H. Janeway,[26] a surgeon who was one of the first to substitute radiation for surgical excision in the treatment of early lip cancer. As will be seen later, the methods now in use consist of either radiation or surgery or a combination of the two, depending upon the clinical course of the given case.

TO BE CONTINUED

OBSERVATIONS ON THE PREVENTION AND TREATMENT OF POSTOPERATIVE ATELECTASIS AND BRONCHOPNEUMONIA*

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THE POSTOPERATIVE pulmonary complications that are usually encountered are of two general types: those due to the retention of bronchial secretions and those due to emboli. Although emboli[8, 9, 10, 12] are responsible for a certain percentage of complications, we believe the great majority of instances of postoperative pneumonia and atelectasis are the result of retained bronchial secretions. The emphasis in this paper will, therefore, be upon the complications resulting from the retention of bronchial secretions. Particular consideration will be given to the early recognition of the presence of bronchial secretions, to the measures for preventing the retention of secretions, and to the methods for promoting bronchial drainage when retained secretions are present. When bronchial secretions occur as a result of septic or aseptic emboli, they must be managed in the same way as secretions due to other causes.

The development of postoperative complications when due to retained bronchial secretions is dependent upon two causes. One is the presence of bronchial secretions, which may be due to a mild preexisting inflammation of the respiratory tract, to the entrance of pharyngeal secretions into the bronchial tree either during or following operation, or to the formation of bronchial secretions postoperatively. The second cause is the decreased respiratory and cough efficiency associated with the operation.

The incidence of postoperative atelectasis and bronchopneumonia is importantly influenced by several factors. The location of the operative site has an important influence in determining the frequency with which these complications are encountered. They are noted most often following upper abdominal operations,[20] and their incidence following gastric operations is about twice as great as following operations on the biliary system. Also, they occur more frequently in patients who have chronic cough[25] and expectoration before operation, as symptoms of chronic bronchitis, bronchiectasis, paranasal sinusitis and asthma, as well as in patients with acute respiratory infections. Another factor is the sex difference—postoperative atelectasis and bronchopneumonia being two or two and one-half times as frequent in males as in females. This difference has been attributed to the fact that, normally, females are predominately costal breathers, whereas males are predominately

* Read before the American Surgical Association, White Sulphur Springs, W. Va., April 30, 1941.

diaphragmatic and abdominal breathers. As a result, the postoperative diaphragmatic splinting exerts a more profound reduction in the respiratory efficiency of males than it does in females. Beecher[2] has shown that the reduction in vital capacity following upper abdominal operations is greater in men (58 per cent) than in women (49 per cent), and that the greatest and most rapid rate of recovery takes place between the second and fourth day in women, while in males it is delayed and takes place between the fourth and sixth days. These observations suggest that the greater incidence in males is due to the greater reduction in pulmonary ventilation and to the greater reduction in the efficiency of respiration and coughing after operation. Another possible explanation for the greater incidence in males is the more frequent incidence of cough and expectoration preoperatively.

PREVENTION

As the preoperative condition of the respiratory tract may influence the development of postoperative pulmonary complications, the possibility of a small amount of daily sputum should be sought for by careful questioning,[15] since this is often present and not appreciated or acknowledged by the patient unless he is particularly questioned about it. If sputum is present, care should be taken immediately before the anesthesia is begun to be certain that all secretions have been raised. Furthermore, if a history of expectoration has been elicited, the necessity for maintaining constant removal of these secretions after operation is obvious. When an acute respiratory infection is present, operations of election should be delayed for a considerable period following recovery from the respiratory infection. A delay of only a few days is usually not sufficient to allow complete recovery, and the operation preferably should be deferred until at least two or more weeks have elapsed after the acute symptoms have disappeared. Faulty oral hygiene should be corrected prior to operations of election, even when local or spinal anesthesia is used, for the reason that oral and pharyngeal secretions may gravitate into the tracheobronchial tree during sleep, unless the posture of the patient is regulated to prevent this occurrence.

The type of preoperative sedation should be chosen with care, and those sedatives which cause prolonged sleep or drowsiness after operation should be avoided. A large dose of a long-acting barbiturate, such as nembutal, is inadvisable, and if a barbiturate need be used, it should preferably be of a brief-acting type. The advisability of administrating atropine preoperatively has been questioned by many persons because it increases the viscosity of bronchial secretions, and we believe it should be avoided unless indicated for a definite reason, such as the prevention of excessive salivation during operations in the region of the mouth or pharynx.

Operative Considerations.—The position of the patient on the operating table is of importance in preventing the gravity drainage of oral and pharyngeal secretions into the tracheobronchial tree. Especially in patients with pharyngeal secretions, the head should not be raised on a pillow as this position allows a better opportunity for the secretions to enter the trachea. In

order to overcome the normal posterior deviation of the trachea, the operating table should be inclined to a 10 or 15 degree Trendelenburg position. The normal curve of the upper dorsal spine varies, being as a rule more marked in elderly patients. The trachea accordingly has a greater posterior deviation in elderly than young persons and, therefore, as a rule the greater degree of Trendelenburg position should be used in elderly persons. However, the type of operation or the condition for which it is done may demand that the table be flat or the head of the table elevated.

The available evidence suggests that the incidence of atelectasis and bronchopneumonia is not importantly influenced by the anesthetic agent. It is desirable, however, that the anesthesia should be gauged so that the patient will awaken promptly following the operation. Schmidt and Waters[27] observed that the greatest incidence of pulmonary complications followed the use of ether, and the next greatest incidence followed spinal anesthesia. Brown,[4] however, is of the opinion that the incidence of pulmonary atelectasis is greater following spinal anesthesia than with any form of inhalation or regional anesthesia. He attributes this to the fact that spinal anesthesia definitely inhibits the depth and force of respiratory movements not only during the operation but for a considerable period thereafter. Brown also believes that it is these respiratory movements (both intrinsic and extrinsic) which tend to rid the tracheobronchial tree of foreign matter or secretion.

Jones and McClure,[19] in 1931, called attention to the influence of the transverse upper abdominal incision in reducing the incidence of postoperative complications. As the transverse incision is in the plane of the muscular and aponeurotic fibers of the external and internal oblique and transversus abdominis muscles, the pull of these respiratory muscles during costal excursion tends to approximate and relax the wound rather than to exert tension upon it, as with the vertical incision. Furthermore, the transverse incision offers less opportunity for injury to the intercostal nerves supplying the musculature of the upper abdominal wall. Jones and McClure observed a reduction of pain and more nearly normal respiratory excursion and pulmonary ventilation after the use of the transverse incision. They were impressed by the comfort and ease of breathing in the average short, obese patient following a gallbladder operation with the transverse incision. In a series of 125 consecutive transverse abdominal incisions, most of which were for operations upon the gallbladder, bile ducts and stomach, they noted no instance of postoperative pneumonia or atelectasis. Five patients developed pulmonary embolism which proved fatal in two instances. Jones and McClure state that two or three additional patients developed pulmonary symptoms, such as cough of mild or moderate degree, but other evidences definitely establishing a pulmonary complication were lacking. Their statistics are in striking contrast to the usual incidence of pulmonary atelectasis and bronchopneumonia, which is 5 to 12 per cent and occasionally more, in most series of gallbladder operations. During the last few years the transverse incision has been used at the University of Michigan Hospital with increasing frequency in gallbladder and other abdominal operations, and at present it is used almost

routinely in gallbladder operations. Our observations in these cases agree with those of Jones and McClure in regard to the smoother convalescence. In a series of operations for chronic cholecystitis and cholelithiasis, we have found the incidence of postoperative atelectasis and pneumonia considerably lower than with the vertical incision, but not as low as reported by Jones and McClure.

Postoperative Considerations.—It is highly desirable that the anesthesia and the preoperative medication should allow patients to awaken promptly following operation, thereby enabling them to cough and expectorate by the time they are to be placed in bed. In the event that the respirations are "wet" and that consciousness is not resumed shortly after operation, or that

FIG. 1.—Lateral position. Frontal bronchogram demonstrating dependent drainage of bronchial tree of uppermost lung with patient on contralateral side.

coughing is ineffectual, aspiration of the tracheobronchial tree by catheter suction or by bronchoscopy is indicated. It is believed that hyperventilation with carbon dioxide and oxygen at the conclusion of the operation is in itself not sufficient if secretions are present and cannot be raised by expectoration. When hyperventilation is used, it is generally agreed by anesthetists that a nonabsorbable buffer agent, such as nitrogen, helium or air, should be used in the inhaled gas mixture so that alveolar collapse will not result from the sole use of two rapidly absorbable gases such as carbon dioxide and oxygen.

Elevation of the foot of the bed[13] is advisable until consciousness is resumed, unless circumstances contraindicating this position are present. A considerable degree of the Trendelenburg position is necessary to secure actual gravitation of tenacious secretions toward the pharynx.[1] The foot of the bed may need to be elevated ten to 18 inches (seven to 11 degrees) or more to cause the trachea to become horizontal when the patient is in the supine position. Even so, the posterior segment of the upper lobe and the superior dorsal and subapical segments of the lower lobe remain dependent. For this reason, it is advisable that the patient be turned on alternate sides[26] in order that the maximum benefit of posture will be obtained for each lung during the time that it is uppermost (Fig. 1). As the lower portion of the trachea

usually deviates slightly to the right, dependent drainage of the trachea is obtained when the patient is lying flat on the left side, but the foot of the bed must be elevated to provide dependent tracheal drainage when patient is on

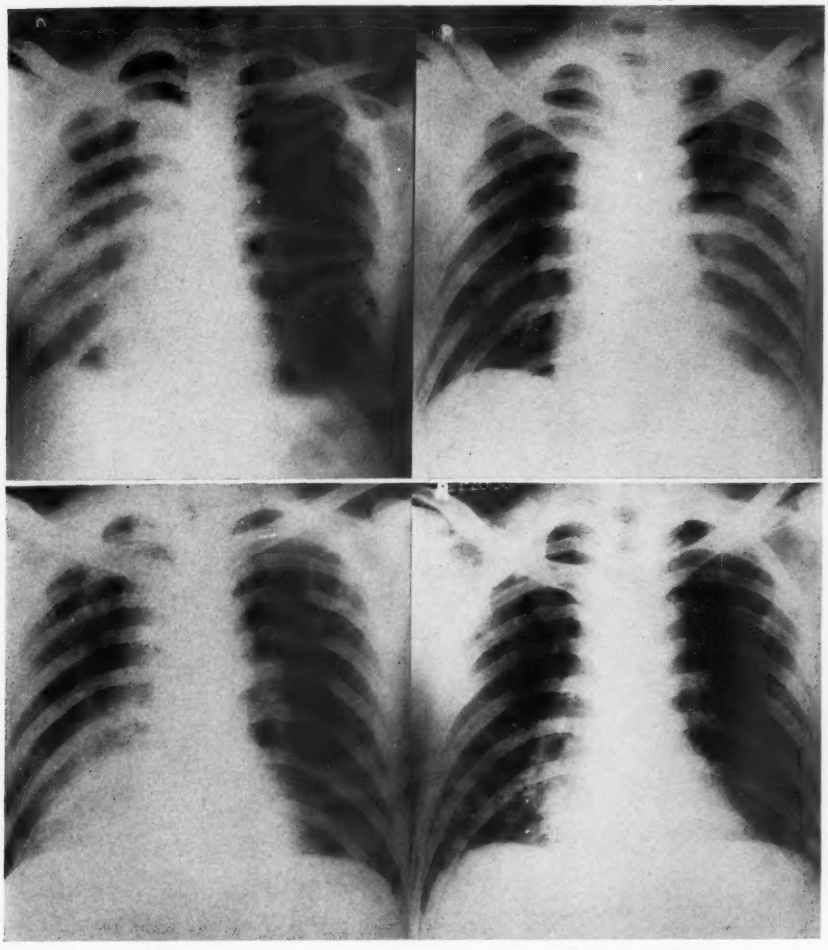


FIG. 2.—M. M., No. 372675: (A) Roentgenogram, Nov. 19, 1938, on first postoperative day following total gastrectomy shows partial atelectasis of right lung. Tracheobronchial suction on three occasions during a period of five hours. Improvement of voluntary cough, so patient treated by alternate lateral positions, one hour on left side and one-half hour on right, and by encouragement of frequent cough. (B) Roentgenogram, Nov. 21, 1938, two days later. Right lung almost clear. Pneumonitis has developed on left. Cough productive and effectual. Subsequent treatment by change of position at hourly and half-hourly intervals with patient kept one hour on right side and one-half hour on left. (C) Roentgenogram, Nov. 23, 1938, two days later. Return of atelectasis of right lower lobe. Left lung now clear. Position now changed more frequently than before to prevent stasis of secretions in more dependent lung. (D) Roentgenogram, Nov. 28, 1938, five days later. Clinical improvement with only slight residual pneumonitis at right base.

This case illustrates the beneficial effect of the lateral position in improving the drainage of the lung which is uppermost for the greater length of time, and the possibility of drainage of secretions into the dependent lung. More frequent change of position (at least every 20 minutes) would have decreased the tendency for involvement of the more dependent lung.

the right side. After consciousness has returned, the use of the lateral position should be continued by having the patient lie on alternate sides for periods of not longer than 30 minutes each, or by alternating the lateral

positions with the supine position. The obvious disadvantage of the lateral position is that it does not provide drainage of the dependent bronchial tree and it also allows secretions from the uppermost lung to gravitate into the dependent lung,[11] unless an uncomfortable degree of elevation of the foot of the bed is maintained. For this reason, patients should not be allowed to remain on one side for a prolonged period. Ordinarily, the maximum time the patient should lie upon one side should not be more than 20 to 30 minutes, but should be governed by the amount of secretions, being shorter when abundant secretions are present (Fig. 2).

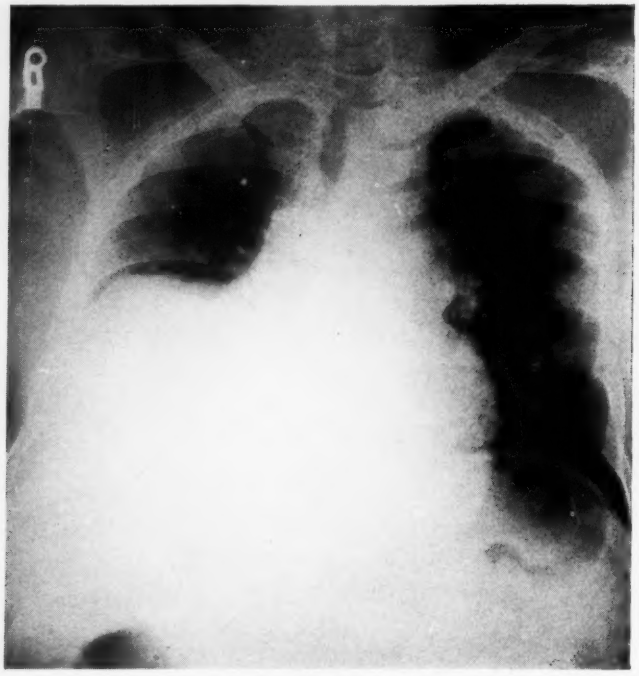


FIG. 3.—Hypoventilation of right lung 36 hours following sigmoid colostomy. Moderate abdominal distention. Breath sounds absent at right base until ventilation of base was obtained by coughing.

The recognition of varying degrees of pulmonary hypoventilation can be obtained by physical, as well as roentgenologic, examination of the chest. The physical examination of the bases of the lungs is facilitated when the lung being examined is in an elevated position (with the patient lying on the opposite side), as this position offers the patient an opportunity to demonstrate the maximum voluntary amount of ventilation of the lower lobe of the uppermost side. Any decrease in the amount of ventilation is, therefore, of greater significance than when the physical examination of the bases is carried out with the patient lying on his back. Ordinarily, following upper abdominal operations, considerable hypoventilation of both bases exists, being greater on the right than on the left[24] (Fig. 3). The degree of hypoventilation is influenced by a number of factors, among them being the location and type of operation,[20, 22] the severity of the operation, the general condition and sex

of the patient, the amount of pain and muscle splinting,[6] the amount of abdominal distention[3] and the degree of obesity. It is a usual finding that the decreased breath sounds at the bases of the lungs following upper abdominal operations can be materially augmented during the examination by having the patient take several deep breaths, by the deep inspiration that follows voluntary cough (Fig. 4) or by hyperventilation with carbon dioxide-oxygen inhalations. We have occasionally seen patients in whom the pulmonary hypoventilation was so marked that breath sounds over the lower dorsal segments of the lower lobe could not be heard on deep breathing or after cough, but could be elicited only by auscultation during hyperventilation with 15 per cent carbon dioxide and oxygen. It is particularly recommended that the character and intensity of breath sounds be elicited during one or all of the above-mentioned maneuvers. If the intensity of the breath sounds reaches or approximates normal and if râles and rhonchi are absent, one can be reasonably certain that the bronchi are not obstructed by the secretions and that the decreased breath sounds heard at the beginning of the examination were due to hypoventilation and not to atelectasis.

FIG. 4.—Examination of base of lungs is preferably undertaken with patient lying on the side, in alternate lateral positions, thereby improving ventilation of uppermost lung. Breath sounds that may be decreased or absent due to hypoventilation, can be augmented when auscultation is done during cough (illustrated), or during hyperventilation with carbon dioxide-oxygen inhalations, thus aiding in differentiation between atelectasis and hypoventilation. Rhonchi due to bronchial secretions may be detected by these maneuvers when otherwise not audible. In the illustration the incision for a gastric operation is being supported by the examiner's hand. The tube in the patient's nose is for continuous duodenal suction.

Roentgenologic examination of the chest following operations on the abdomen and particularly on the upper abdomen showing varying degrees of hypoventilation, as is evidenced by elevation of the leaves of the diaphragm, decrease of costal expansion, and decreased aeration of the lungs, especially at the bases. Pulmonary hypoventilation is evidenced by a generalized haziness and loss of aeration of the lung, especially of that portion immediately above the diaphragm. Hypoventilation will appear more marked than it actually is if the roentgenograms should be made in the expiratory phase of respiration, an occurrence which is noted when patients are unable to cooperate by holding a deep inspiration while the exposure is being made. Therefore, the position of the leaves of the diaphragm and the amount of expansion of the thoracic wall should be ascertained when interpreting the nature of basal densities. Also, the roentgenologic technic used for exposure of the films must be taken into

consideration in interpreting the degree of hypoventilation. As the roentgenograms will ordinarily have been made with a portable unit, and with the patient in a semireclining position, the leaves of the diaphragm will appear higher and the degree of ventilation will appear less than if they had been made with the patient in an upright position and with a standard chest unit. If considerable hypoventilation is present, the increased density of the bases of the lungs may simulate patchy atelectasis or bronchopneumonia.[24]

Hypoventilation decreases the effectiveness of bronchial drainage by an actual reduction in the size and motility of the bronchi and by a reduction in the amount of air that can be expelled from the lungs by coughing. The reduced diameter of the bronchi interferes with the drainage of viscid bronchial secretions and lessens the to-and-fro movement of air which in itself aids drainage. The hypoventilation of the lungs lessens the available amount of air that can be expelled by coughing, thereby reducing the effectiveness of expectoration by decreasing the volume and force of the coughing act. Measures that aid in increasing the ventilation of the lungs are of preventive and therapeutic value and should include frequent change of position, deep breathing exercises, and carbon dioxide-oxygen inhalations. Carbon dioxide-oxygen inhalations are particularly helpful in increasing the ventilation of the lungs in those patients who are unable to obtain hyperventilation by voluntary deep breathing exercises.

The prompt recognition of the presence of bronchial secretions is of fundamental importance in the prevention of postoperative pneumonia or atelectasis, for the reason that retained bronchial secretions are, in our opinion, a precursor to the development of atelectasis and bronchopneumonia in most instances. The patient should be encouraged to cough at periodic intervals of at least every two hours, not only to increase the ventilation of the lungs, but, of equal importance, to determine whether the cough is wet or dry. A wet type of cough signifies the presence of bronchial secretions, and demands that the secretions be evacuated, either by coughing, which will usually be effective, or by actual suction. The character of the respiratory sounds should be elicited by auscultation with the stethoscope placed close to the patient's mouth, in order to determine whether the breath sounds are dry or whether rhonchi or wheezes are present. The presence or absence of rhonchi should also be determined by palpation and auscultation of the chest. As mentioned above, auscultation of the bases of the lungs is preferably done with the patient lying on alternate sides, both bases being examined while the patient is on each side, but particular attention being directed to the physical signs over the base of the uppermost lung. Due to the increased costal excursion of the uppermost lung and the resultant better ventilation of the lower lobe on this side, the breath sounds are heard to better advantage and rhonchi and wheezes are more often audible when the patient is in this position than when he is in the supine position. The character of the breath sounds prior to, during and following a diagnostic cough should be elicited, as rhonchi that are not present on deep breathing are often heard during the inspiration and expiration coincident with cough. When patients are unable to ventilate the

bases well on deep breathing and when the cough is weak, the presence or absence of rhonchi at the pulmonary bases should be determined by auscultation during hyperventilation with carbon dioxide-oxygen inhalations. The early detection of rhonchi is of importance because their presence is the earliest sign of partial bronchial obstruction due to secretions, occurring before the development of frank signs and symptoms of atelectasis or bronchopneumonia.

Voluntary cough is the most important single measure in the prevention and treatment of postoperative atelectasis and bronchopneumonia. The importance of an effective diagnostic or therapeutic cough should be stressed to the patient, in order to obtain his cooperation, even though the act of coughing may be attended with considerable discomfort. The patient should be instructed to take several deep breaths before each cough in order to increase its effectiveness. When the patient is in the supine position a painful abdominal incision should be supported by the nurse or surgeon by gentle constant pressure at each side of the incision, supplemented by firm compression of the costal margins. The patient should also be shown how he can aid himself by supporting the incision.

The position of the patient in bed is important in influencing the effectiveness and ease of cough. When he is in the supine position, the cough is usually more effective if the head of the bed is raised slightly than if the bed is flat or in the Trendelenburg position. Coughing is, however, usually easier and even more effective when the patient is in the lateral position. Manual support of the incision with the patient in this position is aided by the nurse or surgeon standing behind the patient, supporting the incision with one hand[23] and exerting counterpressure over the spine with the other hand. In the lateral position the patient can conveniently support the incision with one hand, which in turn can be supported by the nurse's or surgeon's hand. When tenacious secretions are being raised with difficulty, it is often necessary to offer continuous verbal encouragement to the patient, as well as manual support to the incision, so that the complete expulsion of secretions will be obtained. It is not sufficient merely to ask the patient to cough; he should be instructed how to do so and helped to do so.

The use of a small dose of an opiate (insufficient to obtund the cough reflex) is of advantage in decreasing the amount of pain coincident with coughing, thereby increasing the effectiveness of cough. Steam inhalations with menthol aid in reducing the viscosity of bronchial secretions and are of definite advantage when tenacious secretions are present. The continuous use of a steam tent provides another means for accomplishing the same purpose. Expectorants are of value and are used when they can be administered orally. When purulent bronchial secretions are present, the use of one of the sulfonamide drugs is indicated; our preference at present is for sulfathiazole in view of the fact that pneumococci are usually present.[7, 28]

THE ASPIRATION OF BRONCHIAL SECRETIONS BY SUCTION

The prompt removal of bronchial secretions by suction is indicated as soon as it is evident that the cough is ineffectual and bronchial secretions are

being retained. Two methods are available for the removal of bronchial secretions, one by bronchoscopy[17] and the other by means of a catheter introduced into the tracheobronchial tree.[14] Bronchoscopy possesses the advantage of allowing visual inspection of the bronchi, and by its use one can be certain that the tracheobronchial tree is dry at the conclusion of the aspiration. In cases of postoperative atelectasis and bronchopneumonia, bronchoscopy reveals varying amounts of thick, viscid secretion which at first is mucoid and later mucopurulent. Often a tremendously large amount of secretion is present. The secretion is usually in a semifluid state and only partially occludes the large bronchi; an actual mucous plug completely occluding a bronchial orifice is an infrequent occurrence. Slight swelling and inflammation of the tracheal and bronchial mucosa are usually seen on bronchoscopic examination, and occasionally there are areas of moderate or a considerable degree of edema of the mucosa of the lobar orifices. Bronchoscopy allows the inflamed mucosa to be shrunken with a solution of pontocaine and adrenalin, and the lumen of the bronchi is thereby enlarged. Bronchoscopy also occasionally reveals a localized adherent fibrinous exudate which can be removed by aspiration or by other mechanical means (Fig. 5). Our bronchoscopic findings are the same as those of others in similar cases.[4, 5, 16, 18, 21]

Tracheobronchial suction by means of a catheter introduced through the nose and into the bronchial tree provides a readily available measure for the aspiration of retained bronchial secretion.[14] This method, which has previously been designated as intratracheal suction is more accurately described as tracheobronchial suction, in that the large bronchi, as well as the trachea, are aspirated. Tracheobronchial suction can be used as an alternative to bronchoscopy in most instances when removal of secretions is indicated. It is particularly applicable when repeated aspirations are required, perhaps at hourly or two-hourly intervals. Tracheobronchial suction provides a measure which is usually quickly available when emergency aspiration of secretions is indicated, as it does not require the short delay necessary for the assembling of bronchoscopic equipment. When the amount of retained bronchial secretion is small, tracheobronchial suction will usually be sufficient. When the amount of secretion is large, we prefer bronchoscopic aspiration as the initial procedure, followed by catheter suction at frequent intervals until voluntary cough becomes effective. Occasionally, difficulty will be experienced in introducing the catheter into the trachea, and in such instances bronchoscopy should be resorted to without delay. If a patient is critically ill and cyanotic, bronchoscopy, if expeditiously performed, is frequently a less upsetting measure, and oxygen can be conveniently administered through the aspirating channel of the bronchoscope while the tracheobronchial tree is being cleared by means of the aspirator introduced through the bronchoscope. Oxygen, however, can also be given through a nasopharyngeal catheter during catheter suction of the bronchial tree.

The requirements for tracheobronchial suction are a No. 16 F. soft rubber urethral catheter, a suction apparatus delivering 15 to 25 lbs. suction, and

connecting tubing. We prefer a catheter of the Robinson type with two openings, and it should preferably be new and not softened by repeated sterilizations. A Luken's glass bronchoscopic collecting tube is customarily

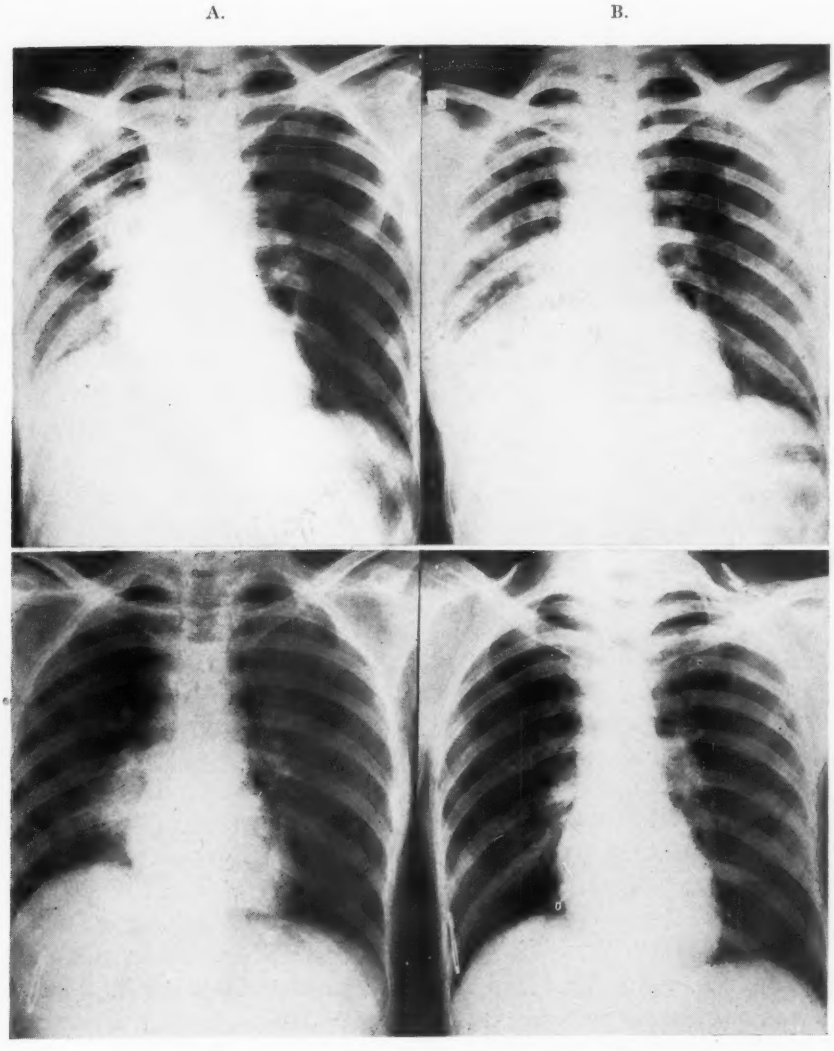
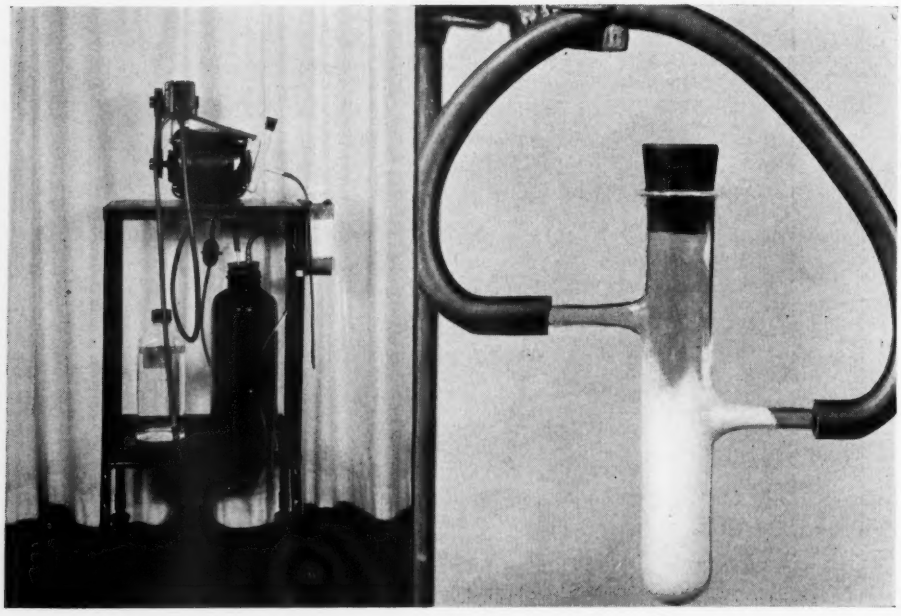


FIG. 5.—L. H., No. 425951: (A) Roentgenogram reveals pneumonitis and partial atelectasis, right lung, 28 hours following cholecystectomy and choledochostomy. Large amount of purulent secretion aspirated by tracheobronchial suction on two occasions. (B) Roentgenogram on following day. Clinical improvement but persistence of fever and large amount of purulent expectoration. In view of atelectasis of right middle lobe, bronchoscopy was believed preferable to tracheobronchial suction, so that middle lobe orifice could be inspected during the aspiration. Bronchoscopy revealed partial obstruction of orifice of middle lobe bronchus by fibrinous exudate, which was removed. (C) Roentgenogram three days later demonstrates residual infiltration of right middle lobe. Convalescence satisfactory. (D) Roentgenogram nine days later shows clearing of infiltration.

interposed in the system, in order to estimate the amount and consistency of the secretions and to obtain a specimen for bacteriologic examination. The open end of the collecting tube is fitted with a rubber stopper with a one-

quarter-inch hole. The hole in the stopper is intermittently occluded with the thumb so that suction will be obtained only when the hole is occluded. If the collecting tube is not available, intermittent suction can be obtained by pinching and alternately releasing the connecting tubing, or by the use of a glass Y-tube, the open end of which is intermittently occluded with the finger.



A. B.

FIG. 6.—(A) Apparatus for tracheobronchial suction consists of suction machine, bronchoscopic collecting tube (optional) and No. 16 F. urethral catheter. (B) Bronchial secretions, more purulent than usual, removed by tracheobronchial suction.

As the amount of secretion obtained is frequently more than the bronchoscopic collecting tube can hold, a pus-trap should be interposed into the system to prevent the secretions from entering the suction apparatus (Fig. 6).

The catheter is introduced into the tracheobronchial tree without the use of local anesthesia. The patient is placed in the semi-Fowler position, the neck is flexed slightly and the tongue is pulled forward by the operator in order to elevate the epiglottis. The catheter is then introduced through the nose, using the side which is the more widely patent, and it is directed posteriorly until the operator feels it touching the larynx. The catheter is then withdrawn 1 or 2 cm. (Fig. 7) and the patient is asked to take a quick deep breath. The catheter is then quickly advanced into the trachea during deep inspiration. If this maneuver is unsuccessful, the patient is asked to cough and the catheter is quickly advanced during the deep inspiration following cough. Unless pharyngeal secretions are present, suction is not applied until the catheter has been introduced into the trachea. During the introduction of the catheter into the trachea, the operator maintains traction upon the tongue in order to prevent the patient from swallowing. The operator is assured that the catheter is in the trachea and not in the esophagus by the

onset of coughing, the passage of air through the catheter, or by huskiness of the voice when the patient is asked to speak.

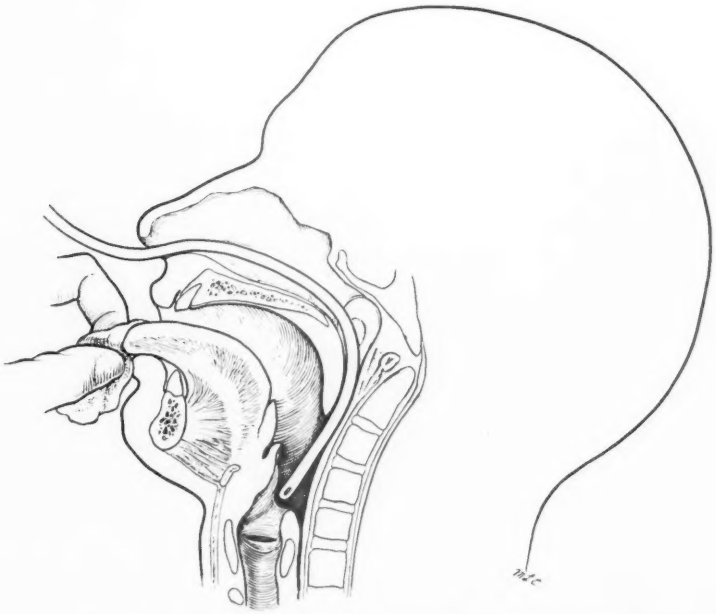
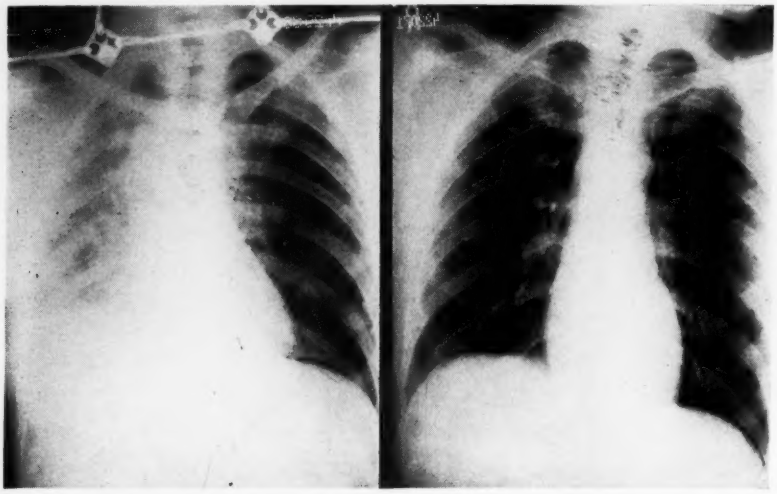


FIG. 7.—Diagram illustrating method for introduction of catheter into trachea. Tongue pulled forward to raise epiglottis, thereby opening passageway for catheter.

After the catheter is in the trachea, the head of the bed is lowered to the horizontal position. Suction is then applied for several seconds and tracheal secretions, if present, are aspirated. The suction is then stopped and the patient is asked to take several deep breaths, following which the suction is again applied for several seconds. This sequence is repeated until the trachea is dry. The catheter is then introduced into the bronchial tree of the more involved lung. Ordinarily, the catheter enters the right bronchus, as it is more nearly in the axis of the trachea. In order to direct the catheter into the left bronchus, the patient's chin and head are turned far to the right

FIG. 8.—Roentgenogram showing chin and head turned to right, thereby directing catheter into left bronchial tree.

(Fig. 8). Each bronchial tree is aspirated dry, the aspiration being applied intermittently to prevent excessive coughing and cyanosis. The catheter is introduced until it reaches the approximate level of the orifice of the lower lobe bronchus, at which time the outer end of the catheter will be about two to three inches from the external nares. If one side shows a greater involvement than the other, the patient may be rolled onto the contralateral side during



A. B.

FIG. 9.—S. B., No. 422071: (A) Roentgenogram 36 hours following bilateral inguinal herniorrhaphy. Atelectasis, right lung. Bronchoscopy performed same day because of ineffectual cough and retained bronchial secretions. 25 cc. thick mucopurulent secretion aspirated from trachea and right bronchial tree. Cough remained ineffectual. Accordingly, two subsequent aspirations by tracheobronchial suction on same day. Two aspirations by same method on following day until cough became effective. Convalescence satisfactory thereafter. (B) Roentgenogram six days later reveals no pulmonary atelectasis or infiltration.

the aspiration of the more involved lung, so that posture will aid cough in dislodging secretions from the smaller bronchi up to the larger bronchi, where they can be reached by the aspirating catheter. Ordinarily, the procedure of tracheobronchial suction is accompanied by moderate or considerable coughing, which is helpful in raising secretions from the smaller bronchi to the level where they can be removed. It should be emphasized that, unless intermittently applied, the suction will provoke severe coughing and cyanosis, and, accordingly, the suction should be used for periods of only several seconds each, the patient being allowed to take a few deep breaths between each period of suction. The total duration of the procedure varies from two to three minutes, depending upon the amount of secretions present. The amount of secretions aspirated is frequently larger than might be anticipated, the average quantity usually being between 10 to 20 cc.

Following the use of bronchoscopy or tracheobronchial suction, voluntary cough usually becomes more effective due to the improved ventilation of the lung beyond the sites of the obstructing secretions. The improved aeration of the lung makes available a larger quantity of air to be displaced by the bechic blast, and peripheral secretions are raised with greater ease. Voluntary

cough, however, may not become completely effective until the patient's general condition improves.

As the subsequent formation of secretions is to be expected, the patient should be carefully observed for any evidences of retained secretions, and suction should again be instituted when and if there is further retention of secretions (Fig. 9). Owing to the improved bronchial drainage and to chemotherapeutic measures, the accompanying purulent bronchitis subsides and the reformation of secretions gradually lessens. Also, during this interval, the patient's general condition, unless influenced by extrapulmonary complications, gradually improves, and the voluntary cough becomes more effective. The measures mentioned earlier for aiding voluntary cough should be continued, so that voluntary cough will become effective as soon as possible and the need for suction will not be unduly prolonged.

The improvement in the patient's condition following the removal of retained secretions is often striking, especially when the amount of retained secretions may inadvertently have progressed to an alarming degree before recognition. Retained bronchial secretions are obstructing secretions, interfering with the airway to the lungs and preventing adequate ventilation. Accordingly, patients are able to breathe more comfortably following the aspiration of secretions, and cyanosis, if present before the aspiration, will frequently be relieved by the improved pulmonary ventilation. As postoperative atelectasis and bronchopneumonia are usually sequelae of retained secretions, the prompt removal of secretions at the first evidence of their retention will minimize the incidence of these complications and lessen their severity.

SUMMARY

The presence of bronchial secretions, and the decreased pulmonary ventilation and cough efficiency subsequent to operation are vitally important factors in the genesis of postoperative atelectasis and bronchopneumonia. The prompt recognition of retained bronchial secretions is essential in the prevention of these complications, and the methods for eliciting the physical signs of retained secretions are described. The measures for aiding the cough mechanism are discussed and they are frequently effective in providing adequate drainage of the tracheobronchial tree. As retention of bronchial secretions occurs in some instances in spite of these measures, retained secretions should be immediately removed by bronchoscopy or tracheobronchial suction *before* the advanced signs of progressing bronchial obstruction and pulmonary infection have developed. A technic for tracheobronchial suction is described; the simplicity of the technic and its applicability when repeated aspirations are required, merit its more frequent use.

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DISCUSSION.—DR. ELLIOTT C. CUTLER (Boston, Mass.): One of the topics set for discussion at the Stockholm meeting of the International Surgical Society this summer was "Postoperative Pulmonary Complications." I take the contribution of Doctors Ransom and Haight as an evidence of the indestructibility of science at the hands even of totalitarian warfare.

If we view postoperative pulmonary complications as a whole, we may find that at least we know something about it, though, since my first studies with Doctor Morton, in 1916, I feel there are still very large gaps. With the advent of local anesthesia, we have evidence that it matters not what the anesthetic is, and the reports from clinics everywhere in the world have come to this point of view. The same pulmonary complications occur under local anesthesia to-day that occurred in 1900 under the hands of Mikulicz, who wrote the first paper on postoperative pulmonary complications under local anesthesia.

If we study the body as a whole, and take fields of surgery and instances of complications in special fields, we learn a great deal. We find that the general percentage of pulmonary complications for all surgery is between 2.5 and 3 per cent, but when we come to the abdomen, it rises to 12 per cent; and when we come to the epigastrium it rises, in some clinics, to as high as 30 per cent. This is of considerable significance, because it must bear some relation, therefore, to the operative field and something that goes on in the operative field.

Having disabused ourselves, therefore, of the idea that the anesthesia plays a rôle, and having very definite evidence that, apparently, the complications bear a direct relation to the ability of the patient to carry out normal respiration, we have left only one other common factor, which is that these complications occur perhaps 5 to 10 per cent less frequently in females than in males. That has been interpreted by most workers as due to the fact that a man breathes largely with his diaphragm and a woman is a costal respiratory animal.

The proof of these contentions lies in part with adequate studies of vital capacity, and we finished the study of several thousand consecutive surgical operations on whom vital capacity studies have been done daily from the time of admission to the time of discharge, over a period of two and one-half years, and we have had adequate curves of reduction in vital capacity with every surgical procedure.

The reduction varies from a median decrease around 59 to 60 per cent for the epigastrium to practically nothing for the extremities; this correlates, almost exactly, with the incidence of pulmonary complications as a whole.

We felt it was wise to find some remedy for the painful respiration; and sought new drugs and new methods of anesthesia. About the only one that has yielded any benefit is a combination of a long-lasting local anesthetic—eucupin with oil. Under these conditions, eucupin produces anesthesia often lasting for four or five days. In a limited number of patients having upper abdominal incisions, carefully studied by one of my colleagues, we find that, when eucupin is used to block the field, the reduction in vital capacity is about one-half of that in similar patients, similarly operated upon by the same surgeon, when eucupin is not employed to block the field.

It seems reasonable to suppose that if an adequate local anesthesia could be found which would render epigastric wounds painless, and respiration would remain normal, we might greatly curtail this disastrous complication for the surgeon.

The authors of this paper have largely restricted their discussion, as we see, to atelectasis. Now, it is difficult to say what the relative frequency of the various clinical forms of pulmonary complications are. If one includes large pulmonary emboli, the pulmonary emboli constitute about 10 to 12 per cent of the complications. Lobar pneumonia, proven by bacterial study, constitutes only 2 or 3 per cent; and you can divide the rest between the clinical diagnosis of atelectasis, either massive or scattered, or bronchial pneumonia. But if you make a clinical diagnosis of scattered atelectasis, and if the patient comes to autopsy, the professor of pathology may tell you it is bronchial pneumonia. Whether that is only because the late stages of atelectasis reach consolidation or not, we do not know.

The chief gift of this paper to-day—and everything has its gift to science—seems to me to be this ingenious idea of using such a simple method in the wet, blue patient,

as the installation of a catheter into the trachea; and adequate instructions on how to do this have been given. Most of us, I am sure, suck out the mouth, but the addition of tracheal suction will do much.

I have only one other suggestion, which is that if the reduction in vital capacity from pain is an important objective, it is peculiar that all the hibernating animals, from the bear to the bat, do not have this disease, because their respiratory rate is cut down and the vital capacity is almost nothing. So I return again to an old contention of mine—that these complications may result from the promulgation of small emboli up the passageways of the lymphatic current through the pleura of the diaphragm.

Dr. Walter Estell Lee (Philadelphia, Pa.): I hesitate to discuss this significant paper because of my too frequent contributions to the subject in the past.

However, such a paper seems timely, for in our experience, and I suspect it is the same with others, the incidence of postoperative atelectasis is increasing. This, of course, may be due, in part at least, to a more general recognition of the condition by both physicians and surgeons, but it seems to us, in most part, to be the result of more radical and more prolonged surgical procedures.

We now speak of six and one-half- and seven-hour operations, such as Doctor Lahey reported recently, and to maintain anesthesia and complete muscular relaxation for such periods of time, spinal, and particularly continuous (intermittent) anesthesia is being employed almost routinely in many clinics. With such a method of anesthesia, most surgeons are using more and more sedatives in the form of morphine, or some type of barbiturate. Under these conditions the respiratory movements are far more shallow than in inhalation anesthesia, and the cough reflex is depressed or abolished. Under such conditions it is to be expected that the tracheal and the bronchial secretions will tend to accumulate in the dependent portions of the bronchial tree and even in the alveoli.

One should approach the problem of postoperative atelectasis through prophylaxis rather than by treatment, and though the method which Doctor Haight has outlined is ideal, we would suggest that prophylaxis should start with the anesthetist during the operation, when every effort should be made to maintain, at all times, an unobstructed bronchial airway, and not wait until the close of the operation to start aspiration. This can be done very readily by hyperventilation with oxygen under pressure about every 15 minutes, and if there is any excess of secretion, it should be aspirated during this time, and not wait until the close of the operative procedure.

My appeal is that we should not postpone Doctor Haight's suggestion of tracheal drainage until the signs of bronchial obstruction appear postoperatively, but that routine measures in the form of hyperventilation, with oxygen under pressure, during the operation, and that aspiration of excessive amounts of tracheal secretion at the close of the operation and before the patient leaves the operating table should be practiced routinely.

In our original reports we confessed—probably bragged—that we have performed bronchoscopic drainage in some 80 patients during a period of one year. At the present time, in a much larger group of patients, three to five bronchoscopic drainages a year is our average.

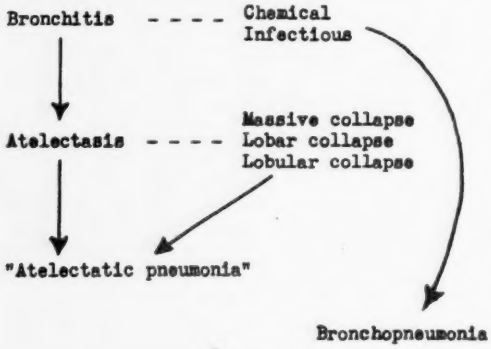

Chart 1.

Dr. Frank H. Lahey (Boston, Mass.): I undertake further discussion only because I think this is such an important subject and because it has played such a part in reducing our mortality.

Albert Miller, of Providence, has shown that if you subject people to anesthesia of any type, which is sufficient in depth to produce relaxation, they breathe largely with the diaphragm. Tracings show that most respiration is carried on by the diaphragm, whether spinal, nitrous oxide or ether anesthesia is used. So, as Doctor Lee has stated, a great deal of our difficulty is probably due to this.

I think we owe a tremendous amount to Chevalier Jackson and Gabriel Tucker, because, so long ago, they called our attention to the value of suction bronchoscopy. One has only to see the intrathoracic goiter patients, delirious in the middle of the night, the secretion sucked out and the temperature down the next day and the patient in a rational state, to realize what an important part this plays in the prevention of pulmonary complications.

Chart 1 is a diagrammatic scheme of the production of these bronchial pneumonias and atelectases. Here is a repetition of what we all have seen, atelectasis so graphically cleared by suction bronchoscopy. Chart 2 shows the temperature and pulse reactions. We could repeat this time after time. There are certain warnings that I think one should note. Our anesthetists should be trained in suction bronchoscopy and, in turn, should train our Fellows in catheter bronchoscopy.

Another point which I think important is that bronchoscopy should be undertaken in the middle of the night, when the condition is discovered, and not at a convenient time the next day. We have demonstrated, in our autopsy findings, how rapidly pneumonitis can develop, and I believe that we should have available the medical men, the roentgenologists, and the suction bronchoscopists to do it, not when it is convenient the next day but whenever the evidence occurs. These patients who have been delirious in the middle of the night, who have had the secretions sucked out and have become conscious and rational, when they have difficulty with their breathing and mucus have even requested its repetition themselves because they have been so much improved. One only has to see the striking results that come from catheter and particularly suction bronchoscopy to be impressed with the fact that this is a real contribution and will, I believe, save many lives. It has played a very important part, I am certain, in making it possible for us to maintain such a low mortality rate in the subtotal gastrectomy cases.

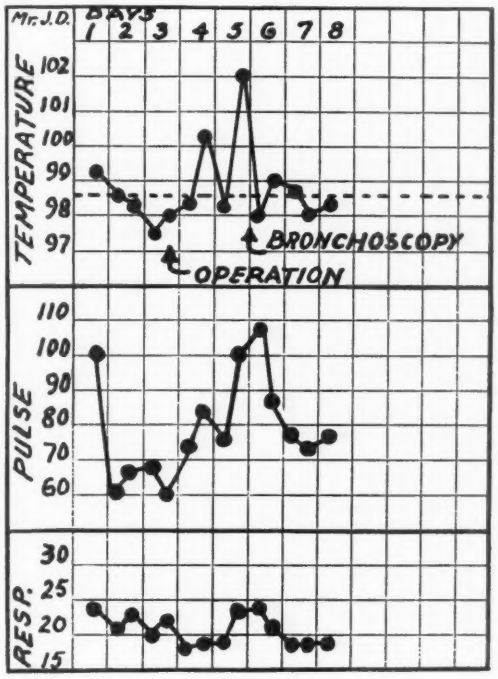

CHART 2.

DR. HENRY K. RANSOM (Ann Arbor, Mich., closing): I wish to mention briefly two points: First, that conservative measures are of inestimable value in the prevention of postoperative pulmonary complications due to retained bronchial secretions. Such measures include (1) the avoidance of excessive sedation and prolonged periods of semiconsciousness following operation; (2) frequent changes in the position of the patient; (3) encouraging the patient to cough, using carbon dioxide inhalations if necessary; (4) good nursing care; and (5) a cooperative house staff. By attention to these details the process can often be aborted and thus prevented from going on to the more advanced and serious stages. These same measures will also be sufficient in many of the early cases of established atelectasis to afford proper drainage of the bronchial tree, and thereby to effect a cure, and, therefore, the more complicated procedures described by Doctor Haight will only occasionally be necessary. Second, during the past several years, transverse incisions have become increasingly popular in the field of abdominal surgery, and especially for operations upon the biliary tract. For the past three years we have employed such incisions and the results have been gratifying. It seems to be true that after healing has taken place, the abdominal wall is more sound, that the incidence of incisional hernia is decreased, that patients are more comfortable during the postoperative period, and that they may be allowed out of bed somewhat earlier. We also gained the

impression that there was a lower incidence of pulmonary complications where such incisions were used. Some ten years ago, a similar observation was recorded in an article by Jones and McClure. They stated that in the series of cases reported by them no instances of postoperative pneumonia or atelectasis occurred. We, therefore, reviewed our cases of simple cholecystectomy during the past six years in order to make a comparison of the pulmonary complications noted with vertical and with transverse incisions (Table I).

TABLE I

PULMONARY COMPLICATIONS FOLLOWING CHOLECYSTECTOMY FOR CHRONIC CHOLECYSTITIS, WITH OR WITHOUT CHOLELITHIASIS 1935–1941

	Type of Incision	
	Vertical	Transverse
Number of cases	346	108
Patchy atelectasis or pneumonia	26 (7.5%)	5 (4.6%)
Massive atelectasis	5	0
Pleuritis	1	0
Infarct or embolism	1	1
	33 (9.3%)	6 (5.6%)
Pulmonary complication chief cause of death	3	0
Pulmonary complication contributory cause of death	1	0

These statistics show that while there was a slight decrease in the incidence of pulmonary complications when transverse incisions were used, this decrease was not as great as we had anticipated. Since the number of cases is relatively small, the statistical evidence is not of great significance, but it does suggest that this is one more detail in surgical technic which may be of importance in further reducing the number of these dreaded postoperative complications.

ROENTGEN RAY TREATMENT OF GAS GANGRENE*

CLINICAL AND EXPERIMENTAL OBSERVATIONS

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AT PRESENT, a wave of enthusiasm for roentgen ray treatment of gas gangrene is sweeping the country. This form of treatment was first attempted by Kelly,[3] in 1928. By 1933, when his first report appeared, he had treated six cases in this way. Because of this report, others were stimulated to try roentgen ray therapy, and sporadic reports of these cases have appeared in the literature. The dosage of roentgen ray has been standardized to 100 r. over the tissues involved with gas gangrene, through two different ports, twice daily, for three days. All of the reports are subject to the same criticism—they fail to consider the level of the lesion on the extremity, the amount of muscle tissue involved and the character and extent of surgical measures employed before or coincidental with the administration of roentgen therapy. Again, it should be emphasized that it is essential to consider whether this form of therapy is the sole cause of fewer deaths and amputations, or whether the surgical and therapeutic measures used at the same time may not be equally beneficial. Since Kelly and Dowell's collected series includes most of the reported cases treated with roentgen ray, and since these authors express the consensus regarding this form of therapy in gas gangrene cases, we will confine our criticisms to their work.

In 1939, Kelly and Dowell[4] collected 132 cases of gas gangrene treated by roentgen ray, with a mortality of 11.3 per cent. Of these, there were 105 cases of gas gangrene of the extremities (level and extent of the lesions not defined) of which 5.6 per cent were fatal. These did not include the nine cases of diabetic and arteriosclerotic gangrene. An analysis of these cases convinced them that "only the very grave cases will die in spite of x-ray irradiation. Accordingly, treated properly, no case should die of pure gas gangrene but rather from other causes." However, they fail to mention the other measures employed coincidental with roentgen ray treatment and these should naturally influence the evaluation of results.

As illustrative of the ineffectiveness of roentgen therapy the following case from the Charity Hospital of Louisiana is presented:

* Read before the American Surgical Association, White Sulphur Springs, W. Va., April 28, 29, 30, 1941.

Aided by grant from the Schwartz Research Fund.

Case 1.—R. T., age 24, received a compound fracture of the right tibia. Twenty-four hours after injury clinical signs of gas gangrene appeared. Incisions, standard roentgen ray therapy for three days, sulfanilamide and serum were employed, but diffusion of the infection was not arrested. A guillotine amputation above the knee was then performed, four days after injury. After amputation, there was no progress of the infection although no special measures were employed.

Further examples of clinical cases which were not benefited by roentgen therapy can be found in the literature. Cubbins, *et al.*,[1] stated that all eight patients with proved gas infection treated with roentgen ray and without surgery or antitoxin, died. Coleman and Bennett[2] reported treating 14 cases with roentgen ray alone with four recoveries and 10 deaths. However, according to these two observers, in the four cases which responded to roentgen ray, wide opening and amputation were responsible for recovery.

Kelly and Dowell[4] believe that amputation is absolutely unnecessary. In support of this view they present a series of 17 cases of "therapeutic amputation," with a mortality of 11.7 per cent. These are compared with 72 other cases of gas gangrene of the extremities treated with roentgen ray but not amputated, with a mortality of 4 per cent. Surgical and medical measures carried out coincidentally are carefully omitted, the interval from onset of symptoms of gangrene until amputation was performed is not mentioned, the level and extent of involvement are not discussed and the degree of toxemia or shock at the time amputation was performed is not given. Any or all of these factors, necessarily, are more responsible for death or survival of the patient than the effect of roentgen ray treatment. It is not fair to ignore the commonest causes of death and consider only one form of therapy in relation to mortality. As further evidence of the uselessness of amputation, they[7] state: "The fact that some of these patients still showed gas in the tissues above the site of amputation, but recovered under x-ray treatment is convincing evidence of its therapeutic value. Accordingly it would seem that those patients lost an extremity unnecessarily inasmuch as they still had the disease after the amputation. Their ultimate recovery can only be attributed to some cause other than amputation." No surgeon can fail to recognize the fact that when the small muscles of the foot alone are involved with gas gangrene, amputation at or immediately above the ankle joint will arrest the progress of the infection and cure the patient, or that when the disease is entirely below the knee joint, disarticulation at the knee or guillotine amputation above the knee will certainly save the patient's life. Surgeons, with adequate experience, can invariably recall instances in which guillotine amputation was performed through discolored muscles, with gas in the subcutaneous tissues. In many of these cases, when the stump was left wide open and the fascia and skin split for some distance above the level of amputation, complete recovery followed without the benefit of roentgen ray therapy or serum.

Not only does Kelly believe that amputation is a useless therapeutic procedure but he and his coworkers,[5] in 1938, stated: "Severe débridement

measures are no longer justifiable" since "early and frequent treatment with small doses of x-ray is the answer to the question of what to do to prevent or to treat an infection with gas-forming organisms."[4] The following case from the Charity Hospital illustrates the fallacy of this statement:

Case 2.—J. H., age 35, received a compound fracture of the left tibia. Within 36 hours of injury, signs of gas gangrene appeared. About 12 hours after the first evidence of gas gangrene was noted, the previous laceration was opened widely, the incision extended upward and downward, and a large amount of necrotic muscle was removed and drainage instituted. The lesion was irrigated with hydrogen peroxide and sulfanilamide was given. Although no roentgen therapy was administered at any time, the infection was arrested and the patient subsequently recovered.

These clinical observations serve to emphasize the rationale of the surgical treatment of gas gangrene, since it meets the bacteriologic and pathologic indications. Roentgen ray therapy, obviously, cannot and will not achieve this end.

The use of roentgen ray therapy in the treatment of gas gangrene is purely empirical. Faust[7] suggests as a possible explanation of the action of roentgen ray: "Recently three Stanford University zoologists have reported that x-rays played upon nutrient fluids are deadly to protozoa by producing small quantities of hydrogen peroxide." A review of this report by Taylor, *et al.*,[8] reveals that they employed 38,400 r. on these nutrient fluids to obtain the lethal effect on protozoa. Such massive dosage is not therapeutically possible in the treatment of human beings. Moreover, it is hardly fair to conclude from their experiments that because with large doses of roentgen ray certain protozoa are destroyed in a sterile yeast medium, anaerobic bacteria can be killed in human tissue by very small doses of roentgen ray.

Very little experimental work has been done to evaluate, scientifically, the effect of roentgen ray in the treatment of gas gangrene. Kelly and Dowell[6] attempted some experimental work but they state: "We could not determine anything to our satisfaction, as it seemed to us that the pig is too small an animal to inject with the virulent gas gangrene and then attempt to cure it with the x-rays. If a real active strain of gas bacillus organisms were used it traveled so rapidly that it was soon necessary to treat most of the pig and the combination of general body irradiation left too much undecided. Some pigs got well and some died and in the end we determined nothing." We have not encountered this difficulty in our experimental work.

Description of Experiments.—Guinea-pigs, averaging 16 to 18 ounces in weight, were anesthetized with ether. An incision was then made over the lateral aspect of the left thigh to expose the shaft of the femur. The muscle layers were split in order to produce approximately the same amount of muscle damage with each individual exposure of the shaft of the femur. With a fine motor-driven drill, two holes were made through the outer cortex of the femur, thereby opening the marrow cavity. This procedure was an at-

tempt in order to reproduce, artificially, a compound fracture without using a splint. A portion of 0.15 cc. of an 18- to 20-hour broth culture of *Clostridium welchii*, a minimal lethal dose, was then placed in the wound, which was closed with interrupted sutures.

The purpose of these experiments was to determine the effect of various chemical and physical agents in preventing the development of gas gangrene in these wounds. The present communication is confined to a comparison of surgical treatment alone with roentgen ray therapy. Exposing these animals to therapy within one hour of inoculation is not in our opinion comparable to treating fully developed gas gangrene. We feel, therefore, that we may, validly, draw some conclusions from these experiments regarding the benefit of surgery and roentgen ray as measures which will control the development of the disease. It was arbitrarily decided to test each individual procedure one hour after inoculation. By this time there was no definite swelling, no gas in the tissues, no discoloration nor loss of contractility of the muscles. The only clinical evidences of infection were slight edema and serosanguineous discharge. A group of 58 animals, with closed wounds, was used as controls throughout the course of the experiment. This group not only gave information regarding the average death time but also insured the continued potency of the organism.

During the whole period of observation, there were about 400 animals operated upon, inoculated, and treated with various agents. It was observed that any animal that lived 72 hours or more did not die as a direct result of gas gangrene. Secondary infection, general sepsis, or complications such as pneumonia were the principal causes of death in animals living beyond this period. In compiling and tabulating the results with reference to gas gangrene, it was decided to consider as survivals all animals living beyond 72 hours. The "average death time" represents an average of the number of hours the animals that were not included in the survivals lived.

Ten animals were treated by simple incision alone, one hour following inoculation. A group of 20 animals were extensively débrided without any further therapy, one hour after inoculation. Forty animals were used in four experiments, in an effort to determine the approximate effective dosage of roentgen ray. From these experiments, it was found that the smaller doses of roentgen ray had a more beneficial effect. Therefore, a standard dosage of 25 r. at 7 Ma., 100 Kv., 21 cm. distance, no filter, with a uniform size port was arbitrarily used. The first group of animals studied received this dosage of roentgen ray alone, one hour after inoculation. A similar group was studied in which the same dosage of roentgen ray was combined with simple incision of the wound. A third group received roentgen ray and extensive surgical débridement.

We, therefore, have a group of animals with closed wounds as controls to compare with the group receiving roentgen ray alone; a group with simple incision to compare with those having incision and roentgen ray; and, finally,

a group with débridement alone as compared with débridement and roentgen therapy.

GROUP I

Control Series—58 Animals

The wounds were exposed and inoculated as described. Following inoculations, the wounds were closed tightly with interrupted sutures. Nothing further was done. Eight in the group survived. In all the animals there was definite clinical evidence of gas gangrene. The survivals might be explained on the basis of two factors: (1) It was impossible to keep some of the animals from chewing the wounds open, thus producing an open wound and thereby lessening the possibility of spread of the infection. (2) Certain animals had a natural resistance to the disease, permitting them to control the spread of the infection. The most interesting feature of the control group, however, is that all the animals showed definite signs of gas gangrene at some time during the observation period. As will be noted in the tables, the average death time for the whole group was 27.7 hours. However, this figure is slightly misleading, since 69 per cent of all the animals died in less than 36 hours, and fully 80 per cent of all the group died as the result of an active gas gangrene. Those animals with active gas gangrene showed extensive involvement of the thigh musculature extending up into the abdominal wall, with lysis of the muscle tissue, a profuse serosanguineous discharge, crepitation in the soft tissues, and a very distinct characteristic odor. Those wounds which were opened by the animal or which opened spontaneously, inevitably became secondarily infected, but no studies of the various strains of contaminating organisms was made.

TABLE I

CONTROL GROUP—CLOSED WOUNDS

Number of animals	58
Average death time	27.7 hours
Survivals (over 72 hours)	8
Animals with definite gas gangrene	58
Animals dying as direct result of G.G.	48
Animals dying of other causes	2

GROUP II

Simple Incision—22 Animals

The compound fracture was produced as described. Following inoculation, the wounds were tightly closed and allowed to remain so for one hour. Then the wounds were opened widely. The skin incision being enlarged to approximately twice its original size, the wound was irrigated with saline in some instances and tap water in others, and then allowed to remain open. No difference could be found in the effect of the agents used for irrigation. The average death time was 32.8 hours, a definite improvement over the control series. Four animals in the group lived. Again, all the animals showed clinical evidence of gas gangrene at some time during the observation period,

and 18 of the 22 (82 per cent) animals died as a direct result of the gas gangrene infection. Simply opening the wound at the end of one hour did not stop the development of gas gangrene, but was of some benefit in helping to combat the infection.

TABLE II

SIMPLE INCISION

Number of animals	22
Average death time	32.8 hours
Survival (over 72 hours)	4
Animals developing gas gangrene	22
Animals dying as direct result of G.G.	18

GROUP III

Surgical Débridement—20 Animals

The wounds were exposed and inoculated as described. Following inoculation, the wounds were tightly closed and allowed to remain so for one hour. At the end of this time, the wounds were opened widely, and all traumatized and devitalized muscle tissue was completely excised. No fragments of muscle sectioned transversely were allowed to remain. The whole lateral aspect of the femur was exposed and, because of the loss of support, the femur fractured with very little trauma. Wherever the femur was broken through completely, the chance for development of active gas gangrene was increased and the chance for actual survival practically *nil*.

In this group, the average death period was 63.1 hours. The most important observation was that only four animals had extensive clinical gas gangrene and two others showed local evidence without spread into the abdomen. Thus, in only six of the 20 animals did gas gangrene develop. The remaining 14 animals failed to show any evidence of active infection at any time. The importance of the additional soft tissue trauma caused by the presence of a fractured femur must again be emphasized.

TABLE III

SURGICAL DÉBRIDEMENT

Number of animals	20
Average death time	63.1 hours
Survivals (over 72 hours)	14
Animals with definite gas gangrene	6
Animals dying as direct result of G.G.	4
Animals dying of other causes	2

ROENTGEN PHASE

Before undertaking any experiments employing roentgen therapy, 40 animals were chosen and, in groups of ten, exposed to varying dosages of roentgen ray, one hour after the usual wound preparation and inoculation. All wounds were allowed to remain closed. All constant factors remained the same, a uniform size port being used throughout every experiment, and the therapy machine adjusted at 100 Kv., 7 Ma., 21 cm. distance, with no filter. Dosages of 35 r., 100 r., 150 r., and 400 r. were administered to each of four

groups respectively. In no instance was the development of gas gangrene prevented, although those animals receiving the smaller doses of roentgen ray did seem to do much better than those receiving the larger doses. This finding agrees with the clinical observations of many authorities. It was, therefore, decided to use a dosage of 25 r. in the remainder of the experiments.

GROUP IV

Roentgen Ray with Closed Wounds—20 Animals

The wounds were exposed and inoculated, after which they were tightly sutured. One hour after inoculation the animals were given 25 r. (100 Kv. —21 cm.—7 Ma.—no filter). The average death time for the group was 29.9 hours. Every animal in the group had gas gangrene, and all died as a result of the infection. Fifteen of the animals died within 36 hours, and all animals within 48 hours.

TABLE IV

ROENTGEN RAY WITH CLOSED WOUNDS

Number of animals	20
Average death time	29.9 hours
Survivals (over 72 hours)	0
Animals with definite gas gangrene	20
Animals dying as direct result of G.G.	20

No doubt, if a sufficiently large series of animals were studied there would have been some survivals. However, their absence does not, we believe, detract from the main fact that all animals developed gangrene, and that the average death time was only slightly above that of the control group, suggesting that any effect from roentgen ray alone was minimal.

GROUP V

Roentgen Ray with Simple Incision—20 Animals

In ten animals, the marrow cavity of the femur was opened. In ten animals, no drill holes were made into the marrow cavity. Otherwise, the inoculation and preparation of the wounds were identical. All wounds were closed for one hour with interrupted sutures, after which the thigh was treated with 25 r. (100 Kv.—21 cm.—7 Ma.—no filter). Immediately thereafter, the wounds were widely opened and the fascial layers incised down to the femur.

The average death time for this group was 39.3 hours. Though gas gangrene developed in every animal in the group, still the survival period was definitely prolonged. It seemed as though the roentgen ray therapy had some slight effect in retarding the spread of infection, but certainly not in preventing its development.

TABLE V

ROENTGEN RAY WITH SIMPLE INCISION

Number of animals	20
Average death time	39 hours
Survivals (over 72 hours)	5
Animals with definite gas gangrene	16
Animals dying as direct result of G.G.	14
Animals dying of other causes	1

GROUP VI

Roentgen Ray with Débridement—30 Animals

The animals were prepared as previously described. The wounds were closed tightly for one hour. The thigh was then exposed to 25 r. (100 Kv.—21 cm.—7 Ma.—no filter). Immediately thereafter, the animals were again operated upon and all devitalized and traumatized muscle was radically débrided.

The average death time for the group was 60.4 hours. Again, the striking feature was that in the majority of the animals gas gangrene failed to develop. Only six of the 30 animals had definite evidence of gas gangrene in their wounds at the time of death. Postmortem examination revealed definite gas bubbles in all six animals. The administration of roentgen ray also required that the animals be handled and tied to animal boards an extra time. Therefore, in this group fracture of the femur occurred more than when only débridement was undertaken. If the muscle tissue remained firm and reddish in color, even though gross secondary infection was present, we did not feel that the animals had succumbed primarily because of gas gangrene.

TABLE VI

ROENTGEN RAY WITH DÉBRIDEMENT

Number of animals	30
Average death time	60.4 hours
Survivals (over 72 hours)	14
Animals with definite gas gangrene	6
Animals dying as direct result of G.G.	6
Animals dying of other causes	10

Discussion.—It may seem, at first, that the control group is unnecessarily large and that this would necessarily alter the statistics, since all other groups were much smaller. This series of experiments represents only a portion of a much larger series in which the effect of various chemical agents have also been studied. Over a period of seven months, whenever ten animals were studied, a group of two to three animals were included in which the wounds were kept closed. The control group, therefore, represents a true average of the death time over this whole period and insures the constant virulence of the organism used, and the ability on our part of consistently reproducing gas gangrene experimentally in guinea-pigs.

In comparing Group I with Group IV, that is, the control group with those animals whose wounds were allowed to remain closed and then exposed to 25 r. dosage of roentgen ray, it will immediately become apparent that the roentgen ray given did not prevent the development of gangrene in any instance. There is apparently some minor effect attributable to the roentgen ray therapy inasmuch as the average animal did not die as quickly, but this figure may not be as significant as it appears at first glance. In the control group, the average death time was 27.7 hours; in the comparable roentgen ray group, 29.9 hours. The most significant observation, in our opinion, was that every animal in both groups manifested definite clinical evidence of gas gangrene.

From a comparison of Groups II and V, that is, the group with simple incision and that with simple incision supplemented by radiation, a bit more evidence as to the efficacy of roentgen ray therapy may be inferred. This fact is not borne out by the average death time (32.8, Group I; 39, Group V) as much as by the fact that four of the 20 animals given roentgen ray failed to contract gas gangrene whereas every one of the 22 animals having surgery alone did. It may be stated, therefore, that roentgen ray has some beneficial effect as a prophylactic measure, but it must also be remembered that this effect of roentgen ray may be more apparent than real, since it is not borne out by a comparison of Groups III and VI.

A comparison of Group III and Group VI shows, immediately, the value of early débridement as a prophylactic measure. Even though vegetative forms of a virulent strain of *Clostridium welchii* were placed in a bed of traumatized tissue, and allowed to incubate there for one hour, it still was possible to stop completely the development of gangrene in 80 per cent of the animals of both groups. The addition of roentgen ray did not improve the results obtained in Group VI.

TABLE VII

RESULTS

Group	Treatment	Animals	A.D.T.	Surv.	Dev. G.G.	Died G.G.	Other Deaths
I	Closed w'ds.	58	27.7 hr.	8	58	48	2
IV	Closed w'ds. and x-ray	20	29.9 hr.	0	20	20	0
II	Incision.	22	32.8 hr.	4	22	18	0
V	Incision and x-ray.	20	39.0 hr.	5	16	14	1
III	Débridement.	20	63.1 hr.	14	6	4	2
VI	Débridement and x-ray	30	60.4 hr.	14	6	6	10

We may conclude, therefore, that as a prophylactic measure roentgen ray alone has no real effect, that it may be of some value as an adjunct to surgery, but certainly can never be substituted for it.

SUMMARY AND CONCLUSIONS

(1) Clinical reports of the fewer amputations and lower mortality rate in gas gangrene as a result of the administration of roentgen ray therapy, which have thus far appeared in the English literature, have been analyzed and found subject to criticism. They fail to consider all the factors concerned, since they omit the most important and probable causes of death, on the one hand, and the known benefits of concomitant surgical measures, on the other.

(2) A case is cited directly refuting assertions made by some of the authors concerning the efficacy of roentgen ray therapy.

(3) A case is presented as illustrative of the value of radical excision of muscles under certain conditions.

(4) Experimental work on guinea-pigs is reported. The results emphasize the value of early débridement in the control of gas gangrene, but fail to show more than slight improvement from roentgen ray therapy.

(5) Earlier and better surgical measures continue to offer the best means of preventing and controlling gas gangrene.

Explanation of abbreviations used in tables:

G.G.—Gas gangrene.
W'ds.—Wounds.
A.D.T.—Average death time.
Surv.—Survival.
Dev.—Development.
X-ray—Roentgen ray.

The kind assistance of Dr. Manual Garcia, Assistant Radiologist in Charge of Therapy, Charity Hospital, New Orleans, La., is gladly acknowledged and greatly appreciated.

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DISCUSSION.—DR. FRANK L. MELENEY (New York, N. Y.): I have followed Doctor Caldwell's work closely for some time, and would like to say a few words about what the subcommittee on Surgical Infections, of the National Research Council, has done in regard to this subject.

It is true that the literature which has appeared has been based on insufficient, insecure, and often unreliable data. However, most of the reports have been favorable. The two which Doctor Caldwell quoted were unfavorable, but the great majority have indicated a clinical impression that roentgenotherapy has been of value in the treatment of gas gangrene.

However, our committee was not satisfied with the data as they appeared, and we asked Doctor Kelly to reassemble his material in order to answer seven questions which we put to him, and which we thought were significant. He did so, and the data which he then submitted to us seemed to indicate that we will have to give careful experimental consideration to this method of treatment. Certain statistics which he has assembled, not only from his own work but from the reports that have appeared in the literature, I would like to quote: In a total of 364 cases, which includes his own as well as those of others that have been reported, the mortality is 11.5 per cent. In those cases in which only a clinical diagnosis was made, without bacteriologic or roentgenologic evidence, the mortality was 17.2 per cent. Where the diagnosis was indicated by the presence of gas in the tissue, without bacteriologic control, the mortality was 17 per cent; and in

those cases in which the diagnosis was confirmed by bacteriologic examination, it was only 8.6 per cent.

In reviewing all of the cases, it seems likely that most of them were really gas gangrene, and that the mortality has been materially reduced, in that series at least, by the use of irradiation, in addition to other methods.

In Doctor Caldwell's experimental work it certainly seems as if he has demonstrated that with these guinea-pig infections roentgenotherapy was of no value whatsoever. Yet I do not feel that we can carry over the results of animal experiments to human cases, particularly with small animals. One reason is that the irradiation has to be given over a large proportion of the body surface and may, of itself, be injurious. Other workers have had similar results as far as guinea-pigs were concerned, but in dogs, it has been demonstrated that roentgenotherapy has been more successful in decreasing the mortality.

We think that all of these different methods of treatment for the prevention and cure of infection in contaminated wounds have to be subjected to an extensive and well-controlled clinical experiment. This has been planned by the subcommittee on Surgical Infections. This plan is recorded in one of the papers which is read by title at this meeting. We are now waiting for adequate financial support to carry that plan through. It is based upon a complete bacteriologic analysis of all of the wounds which we propose studying—burns, badly lacerated, contaminated wounds, and compound fractures—with categories to include those methods of treatment that seem most likely to give favorable results. Among these are irradiation and the newer chemotherapeutic agents. We trust that at the end of the study we will be able to answer this question, which, as our president said, must be solved in the course of time. We hope that by this plan we can solve it in a relatively short period of time.

Dr. Philip D. Wilson (New York, N. Y.): There are just two little points that I thought might be of interest in regard to gas infection, that I learned in England. The first is in regard to débridement: That not only in débridements in general, but particularly in cases of gas infection, it is too often forgotten that the blood supply of the long muscles enters at the upper end and that, therefore, when débridement is undertaken in the center of muscle the distal portion of the muscle should also be removed.

The second was in reference to the studies of sulfathiazole or chemotherapy in the treatment of gas infection; two independent groups of workers in England reported practically identical conclusions: That sulfanilamide had practically no effect on the control of gas infection; that sulfapyridine was without effect likewise; but that sulfathiazole very definitely did have effect; and that the best results were obtained by the combined use of serum and sulfathiazole.

CONSERVATIVE AMPUTATION OF GANGRENOUS PARTS BY CHEMOSURGERY*†

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The chemosurgical treatment of gangrene is an outgrowth of the chemosurgical method for the microscopically controlled removal of accessible cancers.[1] In the course of the cancer investigations, it was observed that following the separation of the tissues which had been chemically killed and fixed *in situ, i.e.,* on the body of the patient, there developed an exceptionally healthy, highly vascular, germ-resistant area of granulations which supported the rapid ingrowth of epithelium and led to healing with a remarkably healthy, smooth, pliable scar. The idea that this excellent healing might be used to advantage in the conservative amputation of gangrenous parts led to the present investigations.

Technic.—The technic of the chemosurgical treatment of gangrene involves: First, the chemical fixation of the gangrenous part; and, second, the surgical excision of all but a thin layer of the tissue thus fixed. A number of fixative chemicals have been used but zinc chloride has been the most satisfactory. This chemical is incorporated in a concentration of about 40 per cent in a special plastic base.[2]

The steps in the technic may be illustrated by the accompanying diagram showing a gangrenous great toe and a gangrenous sinus which extends several centimeters up along the flexor tendon sheath (Fig. 1). The first step is to render the surface keratin permeable to zinc chloride by applying a keratolytic such as dichloracetic acid. The zinc chloride paste is then applied to the toe in a layer 2 Mm. thick, in order to fix the toe to a level somewhat proximal to the limits of the visible gangrene. The material is held in place by a cotton dressing, and excessive drying is avoided by covering with a second layer of cotton, spread with vaseline. Although usually unnecessary, orders are written for analgesics to be given as required.

After about 24 hours, the entire toe has been fixed and can be amputated with a scalpel and bone rongeur (Fig. 1 A). Since only fixed tissue is incised, there is no pain or bleeding from this procedure unless the incision is inadvertently carried into living tissue. If bleeders are encountered, they are

* Read in part before the American Surgical Association, White Sulphur Springs, W. Va., April 30, 1941.

† This project was aided by the Thomas E. Brittingham Fund, the Jonathan Bowman Memorial Fund and the Wisconsin Alumni Research Foundation.

coagulated by applying small squares of fixative-impregnated gauze under momentary pressure.

If the cut-surface presents an area of soft grayish tissue (Fig. 1 B) it is necessary to carry fixation farther. Often gangrenous sinuses extend some distance up along the tendon sheaths, periosteum and other structures. Fixation and excision is repeated until a gangrene-free saucerized area results (Fig. 1 A, level of amputation at three days). Then sterile vaselined gauze

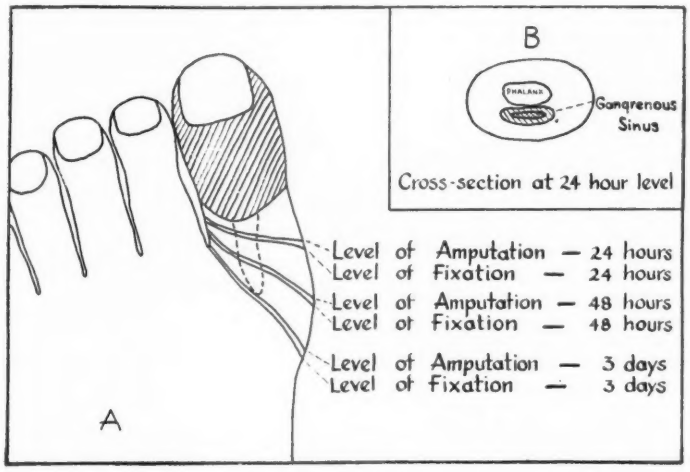

FIG. 1.—Diagram showing the technic for the chemosurgical amputation of a gangrenous toe. (A) Dorsal view. The shaded area represents the visible gangrene. The dotted line indicates the location of a deep gangrenous sinus. Notice that the level of amputation at each 24-hour interval is just distal to the level of fixation; thus, incisions are made only through fixed tissue. Also notice the way in which the wound is kept saucerized. (B) Cross-section at the level of amputation at 24 hours. The gangrenous sinus, which in this example followed along a tendon sheath, is easily distinguished by its softness and darker color from the surrounding nongangrenous tissue which in the fixed state is firm and grayish-white.

dressings or warm compresses are applied, and separation of the thin final layer of fixed tissue is awaited. In favorable cases, most of this layer can be removed after a week or ten days. The bone is left for another week or so to allow a line of demarcation to form between the fixed and unfixed bone. Adhesions are allowed to form around tendons so when they are cut they will not retract into their sheaths—forming sinuses which may cause recurrence of infection and gangrene. Bettman's[3] scarlet red-oxyquinoline sulphate gauze is used to promote healing and to prevent infection. The patient may walk around during healing.

Results.—Of a total of 66 gangrenous extremities, occurring in 60 patients, healing occurred in 40, or 60.6 per cent (Table I). In diabetic gangrene, the results were better than in plain senile arteriosclerotic gangrene. Thus, in 58 cases of diabetic gangrene healing occurred in 63.8 per cent, while in six cases of arteriosclerotic gangrene healing occurred in only 33.3 per cent. One case of gangrene, in a case of Buerger's disease, was nearly healed when the patient developed an acute recurrence of circulatory impairment; the ulcer widened and became so painful that the leg was amputated, though the gangrene did

not reappear. One case of frost-bite gangrene involving the tips of four toes responded well.

Of the 26 unsuccessful results ten were due to failure of the basal layer of fixed tissue to separate. In six, there was extension of the gangrene, in one, extension of purulent infection, and in one, extension of gas bacillus infection. Four signed their release and four died of intercurrent diseases before healing occurred.

TABLE I

RESULTS OF CONSERVATIVE CHEMOSURGICAL AMPUTATION IN GANGRENE OF VARIOUS ETIOLOGIC TYPES

Etiology of Gangrene	No. of Lesions	No. Healed	Per Cent Healed
Diabetic arteriosclerosis	58	37	63.8
Senile arteriosclerosis	6	2	33.3
Thrombo-angiitis obliterans	1	0	0
Frost-bite	1	1	100.0
Total, all types	66	40	60.6

It should be pointed out that these statistics refer to an essentially unselected group of cases in which a number of obviously poor subjects were included, and that the cases treated during the developmental period are included as well as those treated after the technic was perfected.

There were no deaths attributable to the procedure in this series, and in no instance was there a breakdown of the scar once healing had occurred, even though gangrene might occur elsewhere on the same or opposite extremity.

FIG. 2.—Case 1: Diabetic gangrene of right great toe. (A) Before chemosurgery. (B) Ten days later, showing excellent granulations. (C) Six months later, showing healthy scar.

The following case reports illustrate the results of chemosurgery in some of the commonly-met forms of gangrene.

CASE REPORTS

Case 1.—F. W., male, age 57, diabetic. Four months before admission the left great toe had been "burned" by kerosene which had been spilled on a felt slipper. The resulting sore failed to heal despite warm compresses. Soft gangrenous tissue, purulent exudate, and spicules of bone were observed in the deep ulcer (Fig. 2 A.) The diseased tissue was fairly well-demarcated from the surrounding tissues, which showed a moderate amount of inflammatory reaction. The dorsalis pedis and posterior tibial pulsations were moderately strong. Chemosurgical amputation was complete in three days. Seven days later the basal layer was removed, revealing excellent granulation tissue (Fig. 2 B).

Healing was uneventful and a healthy scar was observed on a check-up visit six months later (Fig. 2 C).

Case 2.—D. M., male, age 73, with senile arteriosclerosis, no diabetes. For one year prior to admission the left fourth toe had been more or less inflamed and painful. During the past three months the entire toe had become gangrenous despite conservative treatment with warm compresses at another hospital. The junction between the gangrenous and living tissues was fairly well-defined, and there was a copious, odoriferous, purulent exudate (Fig. 3 A). The adjacent tissues were slightly inflamed.

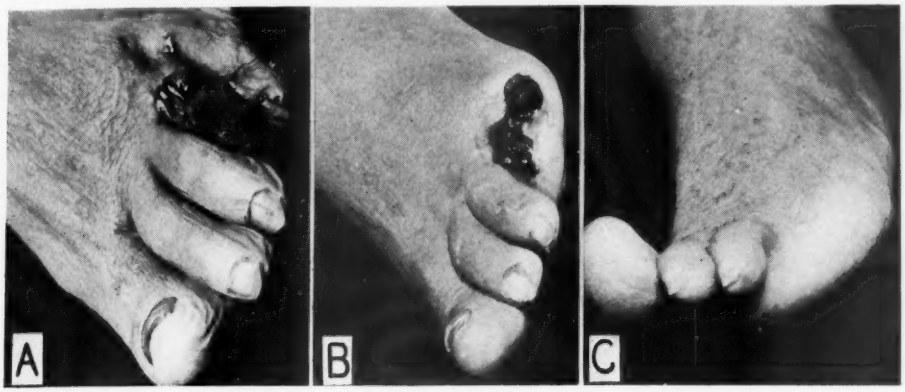

FIG. 3.—Case 2: Senile arteriosclerotic gangrene of the left fourth toe. (A) Before chemosurgery. (B) Twenty-four days later, showing skin growing across granulation tissue. (C) Three months later, showing excellent scar.

Four days were required for chemosurgical removal of the gangrenous toe and a sinus which extended into the dorsum of the foot. The fifth toe was also amputated, since its blood supply could not be preserved. The basal layer of fixed tissue was removed 12 days later, and in another six days the fixed bone was removed. By the twenty-fourth day, the granulations were excellent and epithelization was progressing rapidly (Fig. 3 B). A healthy scar resulted (Fig. 3 C).

Case 3.—C. C., female, age 58, diabetic. Six weeks before admission a sore developed at the base of the left fourth toe which became red and swollen. Bone destruction caused the toe to become shortened and flabby. Five days before admission the second toe suddenly turned black. Midthigh amputation was advised but was refused by the patient. Copious, foul, sanguino-purulent material exuded from sinuses at the base of the toes. The entire foot was red and swollen (Fig. 4 A).

The viable third and fifth as well as the gangrenous second and fourth toes were chemosurgically amputated because the infected gangrenous sinuses involved the bases of all toes except the first. Five days were required for removal of the affected tissues because the copious exudate diluted the fixative chemical. Warm compresses were applied and in 12 days the basal layer had separated. Healing was uneventful and the result was a usable foot (Fig. 4 B).

Case 4.—C. M., male, age 57, diabetic. One month before admission the left foot began to swell, and in one week it ruptured over the ball of the foot, draining large amounts of pus. Despite boric acid compresses, incisions, and Dakin's irrigations, the sinuses extended back to the heel and through the foot to the base of the fourth and fifth toes on the dorsal surface. The third toe had recently become gangrenous (Fig. 5 A and B). The affected tissues were only fairly well-demarcated from the surrounding tissues but the inflammatory reaction was marked. The dorsalis pedis and posterior tibial pulsations were moderately strong. There was a fairly good histamine wheal reaction on the dorsum of the left foot.

The lateral three toes were amputated by the fourth day, and the walls of the gan-

grenous sinuses treated by inserting gauze, impregnated with the fixative, to prevent the chemical from being washed out by the exudate. By the fifteenth day, the basal layer of fixed tissue had separated on the dorsum, and a few days later the plugs of fixed tissue were removed from the sinuses (Fig. 5 C and D). The sinuses were collapsed by pres-

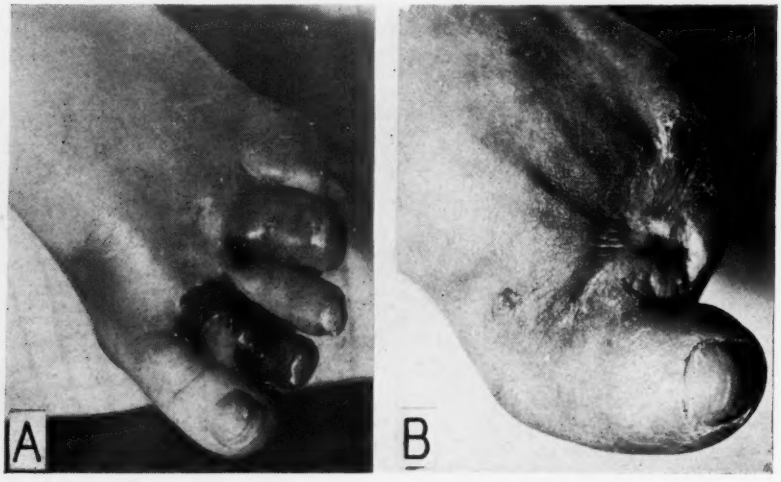

FIG. 4.—Case 3: Diabetic gangrene of the left second and fourth toes with gangrenous sinuses at bases of all but the great toe. (A) Before chemosurgery. (B) Eleven months later, showing usable foot.

sure-dressings so the walls healed together. By this means, it was possible to preserve a good bearing surface, enabling the patient to walk any distance without discomfort (Fig. 5 E and F).

Case 5.—K. P., female, age 74, diabetic. Six weeks before admission the patient had removed a callus from the plantar surface of the right great toe. This toe became swollen and painful. Despite conservative treatment in the hospital with warm compresses, incisions, and Dakin's solution irrigations, the plantar and medial surface of the great toe became gangrenous and the entire anterior part of the foot became riddled with gangrenous sinuses. A small area of gangrene also developed on the dorsum of the foot (Fig. 6 A). The gangrenous areas were fairly well-demarcated from the surrounding tissue and the inflammatory reaction was marked. The dorsalis pedis pulsation was strong.

Refusing the advised midthigh amputation, the patient consented to chemosurgical treatment. The anterior part of the foot was removed in nine days. Large pockets filled with pus and gangrenous material were encountered. At the end of two months the basal layer of fixed tissue, including the bone, had separated and healing was well under way (Fig. 6 B). At a check-up visit, ten months later, the stump had healed well (Fig. 6 C) and the patient could walk on the foot, with only a slight limp.

Prediction of Outcome.—In order to determine what factors are most important in predicting the outcome of chemosurgical amputation in a given case, all referred cases were accepted for chemosurgery, whether or not it was thought that healing would occur.

The more significant prognostic criteria are summarized as follows:

(1) Diabetic gangrene has a better prognosis than the senile arteriosclerotic type. Doubtless, the difference depends largely upon the predominant influence of infection in most cases of diabetic gangrene as contrasted

with the predominant influence of ischemia in most cases of arteriosclerotic gangrene.

(2) The younger the patient, the better the prognosis.

(3) The more definite the demarcation between the gangrenous tissue and the living tissue the better the chances for healing.

(4) The greater the reaction of the living tissues to the gangrenous tissue, as indicated by redness, swelling, heat and purulent exudation, the better the

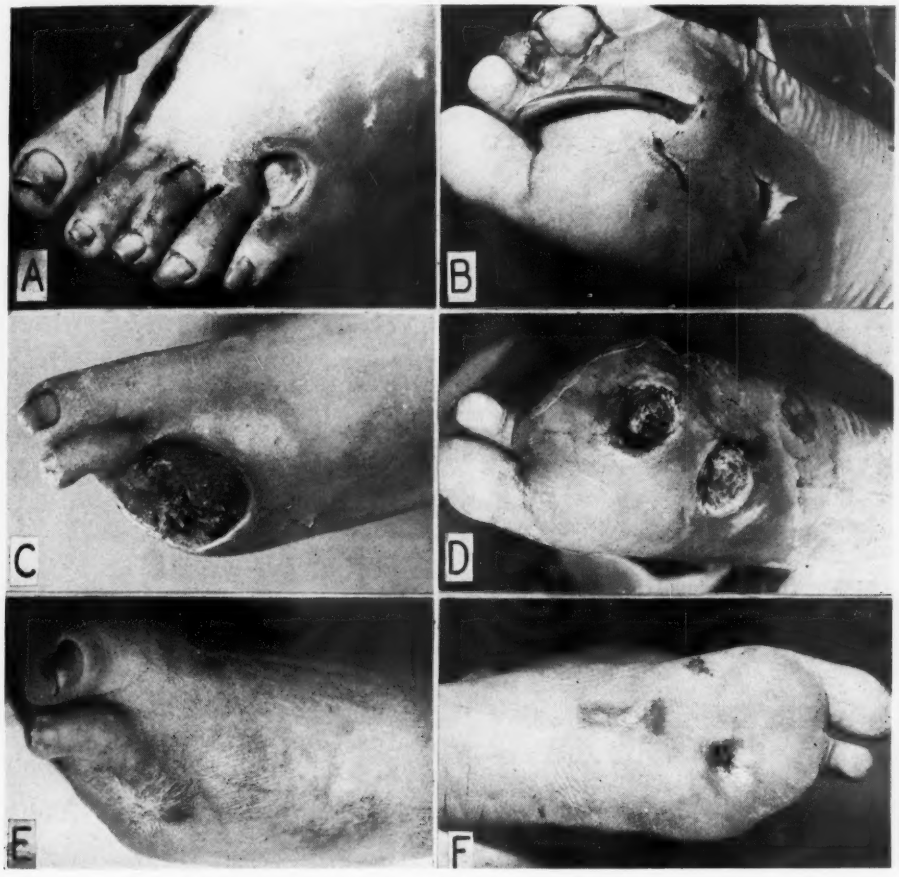

FIG. 5.—Case 4: Diabetic gangrene of the left third toe, with interconnected gangrenous sinuses on dorsal and plantar aspects of foot. (A and B) Dorsal and plantar views before chemosurgery. (C and D) Fifteen days later, showing granulation tissue dorsally and adherent fixed tissue in the plantar sinuses. (E and F) Six months later, showing well-healed scars and good weight-bearing surfaces.

outlook. In other words, a wet infected gangrene in a markedly inflamed foot has a better prognosis than a dry ischemic gangrene in a pale, cool, unswollen foot.

(5) In general, strong pulsations in the dorsalis pedis and posterior tibial arteries are good prognostic signs, but their absence does not necessarily indicate a poor prognosis, because collateral circulation may be efficient.

(6) A high degree of arteriosclerosis as indicated by palpable thickening

of the radial vessels and by calcification, shown in roentgenograms of the feet, is often, but not always, indicative of a poor prognosis because a good arteriolar and capillary circulation may be present in spite of markedly sclerotic arteries.

FIG. 6.—Case 5: Diabetic gangrene of the left great toe and dorsum of the foot, with honeycombing of the entire anterior part of the foot by pus-filled gangrenous sinuses. (A) Before chemosurgery. (B) Two months later, showing skin closing in over granulation tissue. (C) Ten months later, showing functional stump.

(7) The histamine wheal test is an excellent indicator of capillary function and, hence, of prognosis, but the same information can often be obtained by noticing the degree of inflammatory reaction to the gangrene.

The rapidity with which the gangrene had progressed, the extent of the gangrene, and the amount of bone destruction were essentially without prognostic significance. In diabetics, the duration, severity, and control of the diabetes were unimportant in estimating prognosis.

That the efficiency of circulation in the extremity is a prime factor in determining the outcome is indicated by the finding that in 32 extremities with "fairly good" circulation, healing resulted in 93.8 per cent—there were two failures, one due to gas bacillus infection which was at ankle level when treatment was started, and one to cardiac failure in a patient who was severely

decompensated at the beginning of treatment. On the other hand, in 34 extremities with a "poor" or "fair" circulation, healing occurred in ten, or 29.4 per cent. The fact that 29.4 per cent of the latter group healed, indicates that the prognostic criteria listed above are not infallible.

The Therapeutic Test.—The only absolutely certain means to determine how a given case will respond, is to chemosurgically amputate the gangrenous part and observe the lesion for ten days. If by this time the layer of fixed tissue has not begun to separate it may be concluded that it will never do so and the leg should be amputated immediately.

Even if the chemosurgical amputation proves unsuccessful the patient has lost nothing as a result of the therapeutic test except the ten days. Balancing this loss of time, however, is the fact that the chemosurgical removal of most of the infected gangrenous tissue reduces sepsis and renders the patient a better surgical risk than he would otherwise have been.

Discussion.—Why would not conservative surgical amputation be as successful as chemosurgical amputation in a similar group of cases? In the first place, the field is usually more or less infected and fresh-cut surfaces have a lower resistance to infection than the germ-resistant granulations following chemosurgery. The fixative chemical, moreover, sterilizes the treated area. Second, there cannot help but be a certain amount of tissue necrosis in a surgical wound if from nothing else than the incision itself. Ligatures and sutures cause additional necrosis. These areas of dead tissue may act as a source of further extension of the gangrene. Third, the optimum level for amputation cannot be selected as accurately by surgery as by the chemosurgical method which can follow out each unsuspected gangrenous sinus. Being a state institution, our hospital usually receives gangrene cases after they have become quite advanced under conservative treatment elsewhere. Therefore, few conservative surgical amputations have been feasible; however, with the chemosurgical method, a large proportion of the cases are now treated conservatively.

The saving of limbs, made possible by chemosurgery, is of special value in elderly people, usually affected by gangrene, because these patients do not readily become accustomed to artificial limbs. Moreover, the low operative risk with chemosurgery is an important advantage because the major amputations which would otherwise usually be necessary carry a mortality which may vary from 13.1 to 75 per cent in various hospitals in this country.[4] Complicating conditions, such as fever and poor control of diabetes due to infection in the extremity, do not contraindicate chemosurgery; in fact, these conditions are quickly brought under control when chemosurgical treatment is instituted.

Some degree of improvement in the results of chemosurgical amputation may well come from attempts to improve circulation during the critical period when the basal layer is separating. The use of certain proteolytic enzyme preparations during this period also shows promise of improving results in certain border-line cases.

SUMMARY AND CONCLUSIONS

The chemosurgical technic for the conservative amputation of gangrenous parts involves: First, the chemical fixation of the involved tissues; and second, the surgical excision of the fixed tissues. The extraordinarily favorable healing after this procedure made possible successful results in over 60 per cent of 66 conservative amputations in a series of cases which was essentially unselected in regard to circulatory efficiency. There were no breakdowns of the scars once healing had occurred, and there were no operative deaths in this series. The method enables the conservative treatment of gangrene to be extended to a much larger group of patients than previously possible.

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DISCUSSION.—DR. DAMON B. PFEIFFER (Phladelphia, Pa.): Would it be possible to have a little more detailed account of the technic that is employed? I think the results are admirable.

DR. F. E. MOHS: I do not know that I can make it much clearer without actually having patients to demonstrate, but the fixative is applied as a paste to the involved part. Not only the gangrenous tissue is removed, of course, but some normal tissue as well.

The zinc chloride solution is incorporated in a special base which has special properties, which I do not believe I have time to discuss now, but it is discussed in the papers that have already been published on the chemosurgical treatment of cancer. (Cancer Research, January, 1941; Arch. Surg., February, 1941.) It has the property of enabling penetration to be controlled over a wide range of depths by simply altering the depth of application of the paste, so that penetration can be as great as 2 cm. in 24 hours. After the tissue has been fixed to the desired depth, it is simply excised, the incision being made through the fixed tissue and not through the living tissue. If it is seen that the gangrene extends still further, the fixative is applied not only to the gangrenous area but to the whole area, so that the final wound is saucer-shaped.

A PLAN FOR THE STUDY OF WAR WOUNDS*

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THE PRESENT EMERGENCY has come upon us so soon after the last World War that many surgeons who took part then are still available for service in the Army, but most of them are over age 50 and will not be called unless they volunteer. The experience which they obtained in the treatment of war wounds gave them the knowledge of the resources available at that time, and most of them attempted to apply these principles in their civilian practice after their return. But civilian accidents simulating war wounds are relatively few and it is safe to say that, in the minds of many, the details of the methods commonly employed in those days have been forgotten, and the experience itself is fast fading from memory. But the vast number of surgeons who must be called to the colors, if we go to war, will have had no experience whatsoever in the care of war wounds, so we are faced with the problems of preparing ourselves for the work which we will have to do.

It has frequently been said that the most valuable contribution made to scientific medicine in the past war was the development of the Carrel-Dakin treatment, both in the prophylaxis and the treatment of wound infections. This was almost universally acknowledged by the surgeons of the last war and all of them, with hardly any exception, had full opportunity to demonstrate its value in the care of war wounds. It was the general consensus of opinion that its chief value consisted in its ability to liquefy necrotic tissue. However, it was not strongly bactericidal, its period of action was brief and it had to be reapplied at frequent intervals. This necessitated prolonged and frequent dressings with consequent trauma to the wound surfaces. It was also found to be mildly irritating to the tissues and an inhibitor of wound healing.

In the last 20 years, although the Carrel-Dakin treatment has been used continuously in a good many institutions, close inquiry among practicing surgeons reveals the fact that it has gradually gone out of use in most hospitals. A number of substitutes have been proposed and have been employed more or less extensively; and a number of other antiseptics quite different in their

* Presented by title before the American Surgical Association, White Sulphur Springs, W. Va., April 28, 29, 30, 1941.

† Chairman of Subcommittee on Surgical Infections of the National Research Council. This paper is presented with the consent of Dr. L. H. Weed, Director of the Division of Medical Sciences of the National Research Council; Dr. Evarts Graham, Chairman of the Surgical Committee; and Dr. P. H. Long, Chairman of the Committee on Chemotherapeutic and Other Agents. The plan has been developed by and the paper written with the aid of the members of the Subcommittee on Surgical Infections—Dr. John Lockwood, Dr. Perrin Long and Dr. Champ Lyons.

chemical and physical properties have been advocated and have been used to a limited extent.

Of course, civilian, accidental, contaminated wounds vary somewhat from battle casualties but the wounds of bombing victims, so numerous in the present war, are very similar to street accidents. There are, to be sure, penetrating wounds from glass and shell fragments which extensively damage deep tissues, but the great majority of these casualties are caused by falling walls, upheaving pavements, the impact of bodies thrown by the blast, and burns from various causes.

Wounds from air raids and street accidents are often crushing rather than penetrating and street dirt in this horseless age is less likely to carry tetanus bacilli than the soil of cultivated fields, but the gas gangrene organisms of human intestinal origin are ubiquitous. Compound fractures in civilian accidents are often compounded by penetration of the skin by the bone from within outward, thus minimizing bacterial contamination while bone injuries caused by missiles may be associated with gross bacterial seeding. Civilian revolver and rifle wounds are similar to rifle or machine gun bullet wounds among soldiers, but in civilian accidents there are relatively fewer wounds in which there is likely to be extensive trauma such as is produced in the deep tissues by fragments of high explosive shells.

Experience with these civilian wounds during the last 20 years has resulted in a consensus of opinion which was expressed at a Panel meeting of the American College of Surgeons in New York City in 1938. Practically all of those who voiced their point of view, at that discussion, stated emphatically that they believed these wounds should not be treated with Dakin's solution or any other form of antiseptic. All stressed the early débridement of the damaged tissue followed by immobilization of the part, with a minimum of dressing, and either a primary or a delayed primary suture. The author was the only person at that Panel discussion who advocated, in addition to the methods approved by the others, the use of an antiseptic which had recently been found which was nonirritating to the tissues, which favored wound healing, and which effectively inactivated or destroyed the organisms commonly found in contaminated wounds, namely, zinc peroxide. It was pointed out that this substance was not like ordinary antiseptics but it probably performed its bactericidal and bacteriostatic function by the gradual, slow, and continuous evolution of oxygen. It provided a highly oxygenated environment unfavorable to the growth and the toxin formation of the contaminating bacteria and it favored the proliferation of reparative tissue. Its use, however, required that the wound be left open and, because of its insolubility, it could not be used if the wound were to be closed.

At that meeting in New York, very brief mention was made of the possibility of using sulfanilamide by mouth in the prophylaxis and treatment of contaminated accidental wounds, but no one thought of the possibility or at any rate no one suggested that any of the sulfonamide drugs be applied locally to a wound as a prophylactic.

In the last two years, some very great changes have taken place in the attitude of surgeons toward the local use of antiseptics in contaminated accidental wounds, largely due to the fact that the sulfonamide drugs have come into such a prominent place in the treatment of infections. When these were first introduced, they were used principally in hemolytic streptococcus infections, first in septicemia due to puerperal fever and later in other types of hemolytic streptococcus infections of a diffuse nature.

In the early days, the scope and limitations of sulfanilamide were not well-known. It required time to develop experience with the systemic use of this drug to know how much could be tolerated by the patient and what dosage would be effective in any given condition.

The toxic effects of the drug, when given systematically, were at times alarming and the early workers in this field very properly advocated caution in expanding the scope of the new drug. It was taken up perhaps more rapidly by the medical men than by the surgeons because they had no other means to combat such widespread hemolytic streptococcus infections as pneumonia, septicemia, meningitis, and peritonitis. Moreover, it was early shown that sulfanilamide was much more effective when the infective process was diffuse than when it had become localized and was thus amenable to surgery. The effect of the drug in concentrated form on the tissues had not then been demonstrated.

It was soon found that the systemic administration of sulfanilamide would frequently abort hemolytic streptococcus infections which formerly had almost invariably progressed either to widespread cellulitis and septicemia or to abscess formation. Even when administered late in the course of a surgical infection, the drug seemed to modify favorably the course of the disease.

The earlier preparations—prontosil and sulfanilamide—showed unmistakable virtue in the control of the hemolytic streptococcus infections, but when they were applied to lesions caused by other organisms it was found that they were less effective and against some organisms they had no effect whatsoever. This led to the development of related chemical derivatives of all kinds, in the hope that the specificity of sulfanilamide might be modified so as to make it more general in its application. The failure of sulfanilamide to control nonhemolytic streptococcus, pneumococcus and staphylococcus infections was particularly disappointing, but it was soon found that sulfapyridine promptly brought pneumococcus infections to an end in most cases, and later it was discovered that sulfathiazole had an effect not only against the pneumococcus but against many strains of staphylococcus. The gas gangrene organisms and tetanus, as well as the anaerobic streptococci and gram-negative bacilli, however, continued to give very confusing and inconsistent results. The effects on certain of the gram-negative bacilli were likewise variable but some of the *B. coli* infections, particularly of the urinary tract, seemed to be favorably influenced by these drugs for they are largely eliminated through the kidneys and pass through those organs in a much higher concentration than they attain in the blood stream, without obvious damage in most cases. In some in-

stances, to be sure, the acetylated forms of the drugs, particularly sulfapyridine and sulfathiazole, mechanically block the kidney tubules but this difficulty has been largely overcome by a more adequate fluid intake.

Little by little, evidence began to accumulate that these drugs might be used locally without great damage to the tissues. Concentrations a hundred times as great as could be obtained in the blood were possible if the crystalline or powder form of these drugs was placed in the soft parts. Such concentrations in the test tubes seemed not only to be more effective against the hemolytic streptococcus but had some action against certain other organisms not affected at all by the concentrations obtained in the blood stream. Furthermore, it was found that these drugs are absorbed from fresh tissue surfaces or from serous cavities and reach levels in the blood comparable to those obtained by mouth medication. After a variable length of time, the different drugs are then eliminated from the body.

Such observations made by a number of different investigators seemed to warrant the hope and expectation that these drugs might be used locally to combat established infections and to prevent the development of infections in contaminated tissue. It is natural to believe that anything which is effective in the treatment of a disease ought to be still more effective as a prophylactic.

The advent of war brought this problem very promptly to the fore and it was essential that the medical departments of the Army and Navy should attempt to evaluate the newer methods of treatment, in all kinds of medical and surgical diseases to which soldiers or civilians are particularly susceptible when they are concentrated in temporary camps, cantonments, or refuges in time of war. Likewise, it was essential that the newer methods of preventing and treating infection in accidental or intentional wounds and burns be properly evaluated and standardized. The surgeons general of the Army and Navy therefore requested professional advice from the National Research Council. The National Research Council during the past year has appointed certain committees made up of individuals particularly interested in various phases of this problem to reach a consensus of opinion or to formulate plans for studying further those questions not yet satisfactorily answered.

With many diseases common to civilian practice, it was possible for the committees to promptly agree on the best methods of treatment. With regard to the treatment of contaminated wounds, the situation was entirely different. The committee which the National Research Council appointed to consider the problem of infection in war wounds and burns was not able to draw from its own experience or obtain from any of the available literature unmistakable evidence to permit the laying down of any program or directions for the treatment of war wounds. The reluctance of the members of the surgical profession to use any form of antiseptic indicated a prejudice which had to be overcome by incontrovertible evidence: that the use of the new chemotherapeutic agents, either locally or generally, (a) would do no harm; (b) would materially reduce the incidence, the severity and the duration of wound

infection as compared with simpler and safer methods; and (c) would minimize disability, disfigurement and the incidence of death.

In reviewing the articles which have appeared in the medical literature, not only of America but of England and the other European countries, it was apparent that most of the reports represent clinical impressions rather than demonstrated facts. In observations and reports of individual cases without proper controls, credit was given to one out of many methods of treatment used. The bacteriologic studies before, during, and after treatment were for the most part either incomplete or totally absent. Experimental work in laboratories not only failed to recognize fundamental differences between animals and man but fundamental differences between experimental and clinical conditions.

The committee, therefore, reported to the Surgeons General of the Army and Navy that it would be necessary to carry out a comprehensive and well-controlled series of clinical observations in a large number of seriously contaminated wounds among the civilian population, simulating as nearly as possible contaminated wounds as seen on the battlefield or among the victims of bombing raids. In any civilian population, such cases are relatively few in number and in order to obtain a large amount of data in a relatively short time such a study would have to be carried out in a number of different centers. Furthermore, a complete and adequate study from a bacteriologic and chemical point of view could not be carried out in any given center without a staff adequately trained to cover all phases of the problem, prepared to observe the progress of the cases from start to finish in the same institution, and able to correlate and evaluate the assembled data.

A plan has, therefore, been evolved which is designed to obtain data from 2,000 cases in the course of six to nine months' time, with categories covering the various forms of treatment thought most likely to give the best results. It is believed that when the study has been completed it will be possible to lay out a program for the care and treatment of these cases which will be based on incontrovertible proof.

THE KNOWN FACTS TO DATE

Gleaned from our own experience and that of others reported in the literature in the last three years, what facts do we have to start with, which we can use as a basis for such a comprehensive plan? The following facts seem to be well established:

(1) Accidental wounds and war wounds are all contaminated by bacteria.

(2) There is nearly always some damage to deep tissues with extravasation of blood. Sometimes there is tearing of muscle and fracture of bone.

(3) The growth of organisms is favored by the presence of injured tissue and foreign bodies introduced into such wounds.

(4) Certain organisms get into the wound at the time of the accident and others contaminate it later as long as it remains open.

(5) Any organism which gets into a wound may find conditions favorable to its growth enabling it to colonize in the wound and produce its poisons. This may take place as early as two to three hours after contamination.

(6) Motion in any infected tissue increases the activity of the infection.

(7) Surgical débridement will remove a large proportion of the contaminating organisms, foreign bodies, and damaged tissue.

(8) Such wounds cannot be completely sterilized by any known procedure, but the proportion of organisms removed by débridement depends upon the care that is employed and the time after contamination that the operation takes place.

(9) Some débrided wounds may be closed with impunity and may heal without infection, while others so treated may become infected depending upon the completeness of the débridement, the time of the débridement after injury, and the number and virulence of the organisms still present after the débridement has been completed.

(10) Leaving débrided wounds open decreases the probability of serious infection but permits secondary contamination of the wound if proper precautions are not taken. Contaminating organisms may grow on the surface of a wound and not necessarily delay its healing. Hemolytic streptococci coming from nose or throat of attendants not infrequently secondarily infect open wounds.

(11) Patients who have received accidental injuries are frequently in shock when they reach a hospital.

(12) Sulfanilamide may be taken by mouth in doses of six grams initially and six grams in 24 hours distributed at four-hour intervals without serious consequences in most cases and this will maintain a level in the blood of approximately 5–10 mg. per cent as long as it is being given.

(13) Sulfapyridine may be so administered, but it is very nauseating and much more difficult to maintain a constant blood level because of its variable and generally slower rate of absorption.

(14) Sulfathiazole may be so administered and is less nauseating than sulfapyridine but is even more difficult to maintain a constant blood level.

(15) Sulfanilamide when given by mouth is particularly effective against the hemolytic streptococcus and will prevent its growth and spread from almost any portal of entry. It is relatively less effective against other organisms.

(16) Sulfapyridine when given by mouth is effective against the hemolytic streptococcus and pneumococcus, but it has relatively less effect on the other organisms.

(17) Sulfathiazole when given by mouth is effective against the pneumococcus, and to some extent the Staphylococcus aureus, the hemolytic streptococcus and B.coli, but it has relatively less effect on other organisms.

(18) The effect of these drugs when given by mouth has a variable and uncertain effect on the gas gangrene and tetanus clostridia and the anaer-

obic gram-negative bacilli and streptococci.

(19) The bactericidal and bacteriostatic effects of these drugs are handicapped or inhibited by the presence of pus or exudate, or split products of protein, especially peptones, which are present in pus or damaged tissue.

(20) Sulfanilamide, sulfapyridine, and sulfathiazole may produce mild, moderate, or profound intoxication and injury to the red cells, the white cells, and the bone marrow. They may produce skin rashes, fever, jaundice or delirium and the acetylated forms of the latter two may block the kidney tubules and thus produce anuria. In a few cases of idiosyncrasy, these effects may take place promptly after the drug's administration, but usually they do not occur until the second week of administration.

(21) The toxic effects of the drugs generally stop promptly after withdrawal of the drugs.

(22) These drugs may be applied in crystalline or powder form to fresh wound surfaces without serious damage to those tissues. They go into solution in the tissue fluids in concentrations ranging from 200 to 1,000 mg. per cent.

(23) Sulfanilamide is absorbed quickly from such wound surfaces, reaches a peak level in the blood stream in 8 to 12 hours and is eliminated completely in four-five days.

(24) Sulfapyridine and sulfathiazole, absorbed much more slowly, reach a lower and variable level in the blood stream but they both persist longer than sulfanilamide in the blood stream.

(25) A creamy suspension of medicinal grade zinc peroxide powder in distilled water when instilled into a débrided wound, if kept wet, will not injure tissue or have any untoward systemic effect or damage blood cells or any other organs or tissues. To be effective it must come in contact with every part of the wound surface.

(26) Zinc peroxide will kill many of the contaminating organisms and prevent the growth and activity of others. It is particularly effective against all of the anaerobic organisms, the hemolytic streptococcus, and the pneumococcus.

FURTHER IMPORTANT DATA

(1) Evidence has been presented tending to the belief that mild roentgenotherapy will readily penetrate injured tissue and may produce conditions unfavorable to the development and growth of bacteria.

(2) There are numerous reports of clinical experiences with the sulfonamide drugs, with zinc peroxide and with roentgenotherapy which claim but do not clearly prove the value of these agents in the prevention and treatment of infection in contaminated wounds.

(3) There are other substances such as gramicidin, penicillin, and chlorophyl which may have little or no damaging effect on local tissues and may inhibit the growth of certain of the contaminating organisms. These may merit a clinical trial.

(4) Incontrovertible evidence is not yet available to indicate which agent is best or how it may best be employed.

On the basis of this knowledge and these beliefs, we can set up a rational plan for the study of badly contaminated civilian accidental wounds of soft parts and compound fractures and burns or war wounds in the following manner.

THE PLAN

(1) A unit of ten hospital beds should be set up in each of ten of the larger cities of the country in an hospital equipped with every facility for the proper care of seriously injured patients. Arrangements should be made with the city Department of Health or hospitals to promptly transfer such patients by ambulance directly from the scene of the accident to the hospital.

(2) There should be a director to oversee the work of the unit who shall be responsible for the proper care of the patients, see that the proper laboratory tests are carried out, observe and record the clinical progress of the cases from day to day, and collect and summarize all of the data when the case is closed.

(3) There must be a group of surgeons available who are competent to perform all of the surgical procedures necessary in the care of such cases and willing to conform to certain standard procedures agreed upon at the outset of the study.

(4) There must be a bacteriology laboratory fully equipped with personnel and apparatus to make complete bacteriologic analyses and classification of the bacterial flora of all of the contaminated wounds by certain specified aerobic and anaerobic procedures.

(5) There must be a chemical laboratory fully equipped to make chemical studies of blood levels of drug concentration, red and white blood cell counts, and urinalyses. An expert radiologist must help.

(6) When the case is closed, all of the data connected with each case must be recorded on a summary sheet which lists everything that will indicate the effect of the treatment administered and the results obtained. The summary sheet will be so designed that the data may be promptly transferable to punch cards for statistical purposes. One such sheet shall be kept with the hospital chart and a duplicate sent to a central office for carding and filing.

(7) Upon the admission of the patient to the hospital, the director shall coordinate the care and the study of the case. In conference with the operating surgeon, he shall decide whether to have the patient operated upon at once or given certain ante-operative preparations, for example shock treatment. The wound shall be covered with a sterile dressing until the time of operation.

(8) As soon as the patient is in proper condition for operation, he shall be taken to the operating room and anesthetized. The area of the wound or burn shall be cleansed in a specified manner. The wound shall be thoroughly débrided in a standard way.

(9) All of the débrided tissue shall be placed in a sterile container and taken to the bacteriology laboratory within half an hour to be cultured in a specified manner.

(10) The débrided wound shall be washed thoroughly and a culture made from the last wash water, presumably revealing what organisms were still in the wound at the end of the procedure.

(11) If the operation occurs within six hours of the time of the accident, the operator may decide whether or not to close it by suture with or without draining. If it occurs more than six hours after the accident, it must be left open.

(12) Thus there shall be a series of cases of closed wounds and a comparable series of open wounds. In each series, by means of a card system or its equivalent, the cases in each group shall alternate receiving or not receiving some sulfonamide compound by mouth and each of these subgroups shall rotate on local treatment as follows:

Closed wound without sulfonamide compound by mouth.

(a) Nothing locally
(b) Sulfonamide compound locally
(c) Roentgenotherapy

Closed wound with sulfonamide compound by mouth.

(a) Nothing locally
(b) Sulfonamide compound locally

Open wound without sulfonamide compound by mouth.

(a) Nothing locally
(b) Sulfonamide compound locally
(c) Roentgenotherapy
(d) Zinc peroxide locally

Open wound with sulfonamide compound by mouth.

(a) Nothing locally
(b) Sulfonamide compound locally
(c) Zinc peroxide locally

(13) Burned patients will be anesthetized and the burned area will be thoroughly cleansed. All of the skin blisters will be taken to the laboratory for culture. The cases will then be divided into two main categories, one with and one without some sulfonamide compound systemically. In each of these groups, there will be two methods of local treatment. The first will be the application of 5 per cent tannic acid and silver nitrate solutions to all burned surfaces. The other group will have the same treatment for body burns but frequent changes of wet dressings of 1 per cent sodium chloride and 0.25 per cent sodium citrate over gauze impregnated with tulle gras for face and hand burns.

This study, therefore, calls for 12 treatment categories for wounds and four for burns. These categories shall be currently compared with one another by means of the punch cards and shall be correlated with the bacterial analyses so that the best form of treatment for any given type of wound and any given type of bacterial contamination will gradually evolve. If any form of treatment is obviously giving unsatisfactory results, after the study has been going on for a number of months, that category may be dropped and if indicated another added in its place.

The study of the prevention of infection in any given case need not be carried over a period of ten days. By that time, we will know whether or not the treatment has been effective in preventing infection. The case may then be turned over to the general surgical service for further care or convalescence.

It is estimated that data may thus be obtained on 2,000 cases with sufficient numbers in each category to permit an evaluation of these various methods of treatment and this method may then be applied to real war wounds.

It is obvious that such a comprehensive study will cost a considerable amount of money—the largest item of expense will be the hospitalization costs for the patients. The whole study calls for a budget of about a third of a million dollars. But when one considers that this represents the amount of Army life insurance on only 35 soldiers, there can be no question of the appropriateness and value of the investment. The right answer to this question of the best treatment for the prevention of infection in war wounds will save the lives of thousands, lessen the complete or partial, temporary, or permanent disability of many more thousands, shorten the hospital stay, and lessen the hospital costs of all wounded soldiers and civilians, and prove of benefit to mankind for all time.

Such a study cannot be carried out properly under the stress of war. It can only be undertaken in a nonbelligerent country. I believe that it can best be done here in the United States. The time is fast approaching when we may be actively engaged in the war. It may be impossible for us to carry out this essential study if we delay any longer in initiating the project. Further delay or curtailment of appropriations for this study might make it necessary to compromise on this plan by cutting out certain categories, but this would materially lessen its value and it is hoped that this can be avoided.

PROCAINE INJECTION AND EARLY MOBILIZATION IN THE TREATMENT OF NON-WEIGHT-BEARING FRACTURES*

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In the modern treatment of fractures, it is now fairly well recognized that the maintenance of active function during the period of fracture healing reduces the period of disability and, by thus maintaining a normal blood supply, hastens union.

A favorable experience in the application of this principle has led us to examine the possibilities of the method of Leriche. He suggested that non-weight-bearing fractures could be treated by the injection of procaine solution and by early mobilization. His first article[1] appeared in 1928 and, since then, some 30 or more articles, mostly by Leriche and his students, have appeared in the French literature, with scattered articles in the Argentine, Brazilian and English, and one in the American literature. More than 200 fractures have been reported as successfully treated by this method. We wish to discuss, briefly, the theory underlying this method of fracture therapy and to cite the results we have obtained in 84 cases thus treated.

It goes without saying that this form of treatment is contrary to the long-established principles of rest and immobilization as the best method of promoting healing in injured parts. In fact, the accepted medical thought on this subject is probably exemplified by the following question and answer, which appeared in the Journal of the American Medical Association for August 13, 1938[2]:

Question: "Is it considered good practice to inject procaine hydrochloride into a sprained knee as routine treatment? An osteopath nearby is doing this in order that children may continue to play basketball. I advised taping the sprained knee, with rest." M. D., Colorado.

Answer: "A sprain of any kind indicates injury to supporting tissues. A sprained knee should be protected against reinjury and supported either by a splint or by adhesive strapping and an elastic bandage until the injured tissues have had time to repair. Injection of procaine hydrochloride into a sprained joint, to relieve the pain so that activity may be made possible, is a dangerous procedure. The pain which is present, after such an injury, is nature's way of warning the individual that damage has been done and that further activity producing the pain is increasing the injury. The local anesthetic simply paralyzes the warning signal and is as much a mistake as it would be to disconnect the burglar or fire alarm simply because the sound of it annoyed the owner of the establishment in which it had been installed."

* Read before the American Surgical Association, White Sulphur Springs, W. Va., April 28, 29, 30, 1941.

The theory underlying the beneficial effects obtained by procaine injection is extremely interesting. The value of the procaine in the treatment of fractures lies not in the abolition of pain, but in eliminating the vasomotor impulses due to trauma. Albert[3] showed the presence of these reflexes in experimental work, in 1924. He found them most pronounced following articular and para-articular trauma, and noted that the amount of vasospasm seems to bear no definite relation to the anatomic extent of the lesion. He believes his to be an axon reflex, as section of all the anterior and posterior spinal roots does not abolish this vasomotor reaction to trauma. Ochsner and DeBakey[4] have added further to our knowledge of this mechanism in their work on thrombophlebitis. Experimentally, they showed that localized chemical endophlebitis results in marked arteriolar vasospasm of such severe degree that practically all pulsations are lost. They believe that this mechanism is the result of vasoconstrictor impulses originating in the involved segment and transmitted over the sympathetic nervous system, because it can be prevented by performing a sympathectomy or by blocking the sympathetic ganglia with procaine hydrochloride. They have explained the physiologic basis for the edema associated with vasospasm.

Leriche believed that the pain and disability produced by fractures near joints was the result of the same type of reflex. He obtained relief of pain and a resumption of almost normal function by interrupting the reflex arc by the injection of the sympathetic ganglia supplying the part or by local infiltration of the fracture site. We have noted also a reduction of edema following the injection of procaine solution at the injured area. That the abolition of pain *per se* is not the value of this form of therapy is further borne out by Leriche's[5] observation that, when adrenalin is added to the procaine solution (vasoconstriction), the desired effect is not obtained, though the anesthetic effect of the procaine is prolonged. Furthermore, the pain relief persists for eight to ten hours after the anesthetic effect of procaine should have disappeared.

Leriche is so enthusiastic about the value of procaine that he recommends it to be used whether the fracture is mobilized or not. Outland and Hanlon[6] have observed that fractures reduced under local anesthesia and then immobilized in plaster are more pain-free and are accompanied by an earlier resumption of function than when general anesthesia is used. In this connection, it is interesting to cite our experience with a Colles' fracture reduced under local anesthesia and placed in a plaster encasement. The following day the patient was quite comfortable except for pain over the ulnar styloid, which had not been infiltrated the previous day. This pain was relieved by an injection of the cervical sympathetic, and did not recur.

The question naturally arises as to whether or not active function by early mobilization is of more beneficial effect than the procaine injection. In five fractures, excellent results were obtained by early mobilization without procaine infiltration. Three of these were in infants, and in all cases there was no edema or marked pain.

We believe the procaine injection relieves the discomfort and edema, thus permitting early resumption of active function. These two measures allow a more adequate blood supply to be maintained, which produces an early and excellent fracture healing.

Early mobilization is of special value in minor fractures in the region of joints. With maintenance of active function during the period of fracture healing, nature is able to accommodate for the deformities in the articulating surfaces as they occur in the actual use of the joint. When these fractures are treated by immobilization during the period of fracture healing, the accommodation is only for the position in which the fracture is immobilized. This is best exemplified in fractures of the head or neck of the radius. The limitation of motion resulting in these fractures treated by immobilization is well known, whereas treatment by mobilization preserves almost normal function, even with some displacements of the fragments. Fontaine[7] was the first to point out this fact, and our experience has borne out his contention.

Summarizing the theoretic background, a fairly logical sequence of events is that the original trauma produces a reflex vasospasm which causes local anoxia. This increases the permeability of the capillary walls and results in edema, which causes further pain and so *ad infinitum*. Local injection of procaine interrupts the reflex arc, in this way relieving reflex vasospasm, thus reversing the cycle. Thorndike's[8] good results in the use of pressure dressings may well be due to an attack on this cycle at another point, that is, the edema. Improvement in the blood supply and prevention of edema are the desired effects, whether they are obtained by active motion, by blocking the vasoconstrictor impulses with local injections or ganglion infiltration with procaine or by preventing edema by applying a pressure dressing. Active function permits rapid fracture healing and an accommodation for minor articular deformities so that almost normal joint function can be preserved.

Method.—With aseptic precautions, after thorough sterilization of the skin, 1 or 2 per cent procaine hydrochloride solution, without adrenalin, is injected at the point of maximum tenderness. The amount varies, the injection being continued until complete relief of pain is obtained. The involved member is massaged to insure thorough dissemination of the solution and, at the same time, probably aiding the absorption of the local edema. We have used elastic or elastic-adhesive bandages, especially in fractures around the ankle joint, though Leriche apparently uses no supportive dressing. The patient is then instructed to use the part normally but not to put it to a test.

These patients occasionally have systemic effects as manifested by a feeling of faintness and marked perspiration. Many have an increase in pain eight to 12 hours after injection but this gradually subsides. It is well to warn the patient about this. The injections are repeated as deemed necessary, though we have not given them as frequently as Leriche.

Injection and immediate mobilization is not always used as a primary treatment. In fractures with marked swelling due to hemorrhage, we have

applied compression bandages or splints with elevation of the part until the swelling begins to recede. This means three to five days, after which we inject and begin mobilization.

Indications and Contraindications.—Not every fracture lends itself to injection and mobilization. It cannot be used in fractures of weight-bearing bones nor in those which require immobilization dressings for maintaining reduction. It may be used, however, in fractures of non-weight-bearing bones which do not require reduction and is especially indicated in fractures about joints.

Advantages.—The advantages of this method of therapy lie not alone in its relief of pain. One of its chief virtues consists in the ability to permit the patient to resume normal or slightly restricted function at an early date, without the disability of cumbersome splints or plaster encasements and crutches or canes. The final and important advantage is the excellent functional results which can be obtained, avoiding in some instances prolonged and even permanent disability that is often encountered in articular fractures treated by immobilization.

Results.—We have treated 84 fractures by early mobilization, with procaine injections in all but four cases (Table I). All but four cases had satisfactory results. The various types of fractures and the results obtained are discussed in their anatomic groups.

TABLE I

SUMMARY OF FRACTURES TREATED BY PROCAINE INJECTION AND MOBILIZATION

Clavicle	4	Shaft of fibula	1
Upper end of humerus	6*	Around the ankle	22*
Around the elbow	9	Tarsometatarsals	13
Both bones of forearm	1	Phalanges of toes	6*
Radial styloid	5	Ribs	5
Metacarpals	7	Transverse processes of lumbar vertebrae	2
Phalanges of fingers	3*		
Total	84		

* One of these fractures not injected.

Fractures about the Ankle.—The greater number of reported fractures treated by this method have been around the ankle joint. These vary in degree from sprain fractures of one malleolus to trimalleolar fractures without displacement. Campbell[9] believes only minor fractures around the ankle joint should be treated in this manner. He defines a minor fracture as one in which only one malleolus is broken with an intact ligament on the opposite side, as evidenced by the absence of pain on pushing the foot toward the fractured side. Cullumbine[10] increases the indication to those in which there is no displacement. We treated 22 fractures around the ankle joint; of these, there were six sprain-fractures, one internal malleolus, 11 external malleoli, two bimalleolar and two bimalleolar with posterior lipping fractures (Table II).

These cases were all allowed to bear weight on an average of four days after fracture, the quickest weight-bearing being immediate, and the longest 14 days after injury. The average period of disability was 15 days, the

extremes being three and 30 days. This does not mean these patients' ankles were perfectly normal, but they were able to go about their usual occupation without much discomfort. In addition to an average of two injections,

TABLE II

FRACTURES AROUND THE ANKLE

Case	Age	Fracture	Other Treatment	Injections	Weight-Bearing Day	Days, Disability	Result
E. S.	35	Sprain ext. mal.	Elastic adhesive bandage	2	1	5	Good
R. W.	12	Sprain ext. mal.	Splint, 6 days	1	7	14	Good
C. P.	29	Sprain ext. mal.	Strapping	1	1	8	Good
B. O.		Sprain ext. mal.	Strapping	1	1	3	Excellent
W. C.	15	Sprain ext. mal.	Gelatin boot	1	1	13	Excellent
W. F.	22	Sprain tibia	Elastic adhesive bandage	2	1		Good
E. D.	21	Ext. mal.	Elastic adhesive bandage	1	1	7	Excellent
E. F.	15	Ext. mal.	Elastic adhesive bandage	2	7	14	Good
J. M.	26	Ext. mal.	Plaster splint, 2 days	0	3	3	Excellent
S. R.	41	Ext. mal.	Strapping	1	1	10	Excellent
C. W.	32	Ext. mal.	Gelatin boot	2	2	6	Excellent
W. B.	47	Ext. mal.	Strapping	2	12	30	Fair
W. M.	20	Ext. mal.	Splint, 5 days; strapping	2	5	19	Excellent
L. L.	41	Ext. mal.	Gelatin boot	1	1	13	Excellent
M. B.	71	Ext. mal.	Gelatin boot	2	1	22	Good
G. B.	52	Ext. mal.	Gibney boot	2	1	20	Good
C. W.	20	Ext. mal.	Ace bandage	2	14	30	Excellent
F. S.	56	Int. mal.	Strapping	1	2	14	Excellent
P. H.	42	Ext. mal. and posterior lip	None	3	3	12	Good
A. P.	44	Ext. mal. and int. mal.	Strapping	1	1	30	Fair
E. B.	18	Trimal.	Splint, 6 days	1	6	13	Excellent
L. W.	22	Trimal.	Splint, 6 days; Ace bandage	3	6	13	Excellent

practically all these patients had some form of pressure dressing, either elastic adhesive, Gibney boot or gelatin boot. Results were evaluated as follows: 12 excellent, eight good, two fair; none was unsatisfactory. These results were based on the amount of pain the patient experienced, the period of disability, the eventual end-result, and the patient's satisfaction with the treatment.

In these fractures about the ankle, sprain-fractures, fissure-fractures (Fig. 1) and fractures of the fibula above the malleolus (Fig. 2), respond very well to this form of therapy. Greater care, perhaps with temporary (five or six days) splinting, must be exercised in bimalleolar and trimalleolar fractures, in order to insure preservation of the mortise (Fig. 3).

Tarsal and Metatarsal Fractures.—There were 13 patients in this group (Table III). The average period of disability was about ten days, the shortest one being one day and the longest 30 days. Six patients were able to resume normal function in five days or less. Four others were not seen for treatment until six to ten days after the fracture.

The commonest site of injury was the base of the fifth metatarsal. In addition to the procaine injections, adhesive strapping or other support was usually employed and the patient was asked to walk immediately. Practically all patients walked without the aid of crutches following the first injection. An excellent result showing the saving in time and compensation was obtained in one patient (Fig. 4).

Fractures of Phalanges.—In this group are nine cases—six of the toes

and three of the fingers (Table IV). The fractures of the toes were mostly complete fractures of the proximal phalanges.

Fractures of the toes are very difficult to immobilize properly. The average tongue-depressor splint places an additional strain on the fracture site and frequently increases the discomfort. We have found that injection

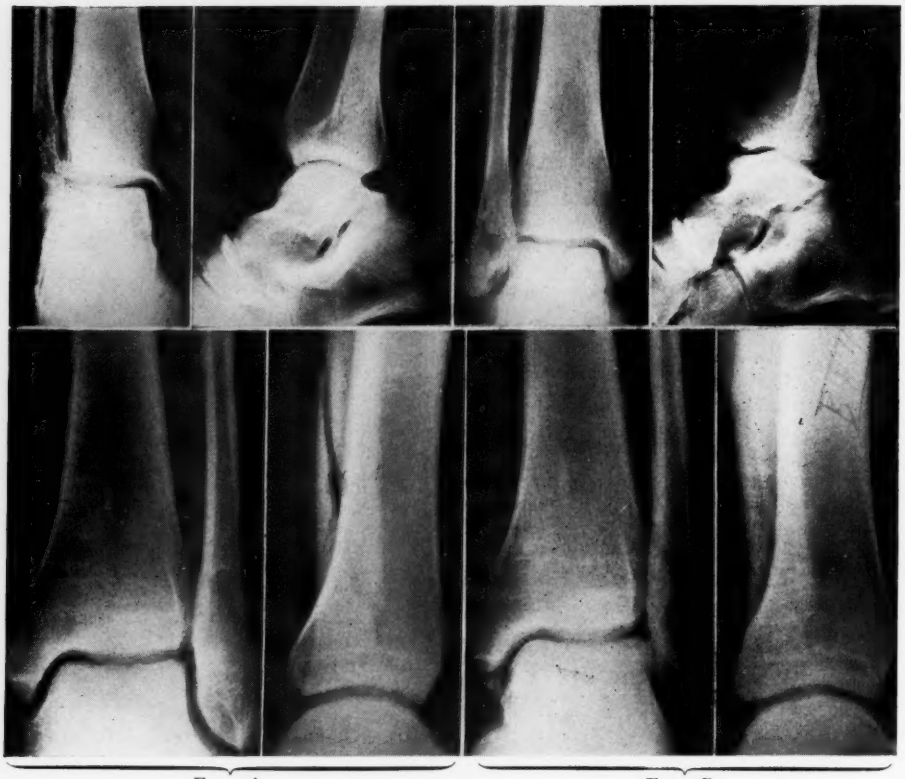


FIG. 1A. FIG. 1B. FIG. 2A. FIG. 2B.

FIG. 1.—(A) Fracture of lower fibula, January 19, 1940. One injection of procaine; elastic-adhesive bandage; crutches for one week; seventeenth day, no pain or disability. Lost three days work. (B) Follow-up roentgenograms, March 13, 1941.

FIG. 2.—(A) Fracture of lower fibula, March 13, 1940. Plaster splint, six days; one procaine injection; elastic-adhesive bandage. Walked with no disability in 14 days. (B) Follow-up roentgenograms, April 19, 1941.

and support with snug adhesive strapping results in rapid union in these fractures, with a minimum of disability and inconvenience (Fig. 5).

Small chip-fractures of the phalanges of fingers are best treated by mobilization. Probably, everyone has seen stiff fingers resulting from immobilization due to adhesions of the extensor tendon. These are extremely difficult cases to treat and we believe they can be prevented by procaine injection and early mobilization.

Fractures of the Upper End of the Humerus.—Six fractures of the upper humerus were treated by injection and early mobilization (Table V). All had impaction with displacement of minor degree. The greater tuberosity was fractured in three cases. In all but one case, some form of fracture

TABLE III

FRACTURES OF TARSOMETATARSALS

Case	Age	Fracture	Other Treatment	Injections	Days, Disability*	Result
R. O.	32	Prox. end 5th metatarsal	Adhesive strapping	2	30†	Fair
R. G.	17	Prox. end 5th metatarsal	Adhesive strapping	2	5	Good
A. Z.	16	Prox. end 5th metatarsal	Adhesive strapping	3	11	Good
F. F.	13	Prox. end 5th metatarsal	Adhesive strapping	1	4	Excellent
L. C.	21	Prox. end 5th metatarsal	None	1	5	Excellent
M. F.	17	Prox. end 5th metatarsal	Strapped, 6 days	2	12	Excellent
J. F.	60	4th, 5th metatarsals	Strapped and rest, 7 days	1	16	Excellent
M. M.	31	3rd metatarsal	Strapping	1	10	Good
C. L.	47	2nd metatarsal	Strapping	2	1	Excellent
P. D.	45	1st metatarsal	Gelatin boot	1	5	Good
J. D.	20	1st cuneiform	Encasement, 7 days	1	10	Excellent
N. H.	20	Sprain tarsometatarsal joint	None	2	9	Excellent
F. F.	13	Os vesalianum	None	2	5	Excellent

* Average period of disability: 10 days.

† Patient did not cooperate; would not try to use foot.

TABLE IV

FRACTURES OF THE PHALANGES

TOES

Case	Age	Fracture	Other Treatment	Injections	Days, Disability*	Result
D. S.	28	Proximal phalanx 1st toe	None	0	2	Excellent
R. L.	22	Distal phalanx 1st toe	Strapping	1	14	Excellent
E. C.	35	Proximal phalanx 5th toe	Splinted, 8 days before, elsewhere	1	31	Excellent
M. L.	24	Proximal phalanx 1st toe	Strapped	2	1	Excellent
W. J.	18	Proximal phalanx 2nd toe	Strapping	1	3	Good
J. B.	40	Proximal phalanx 5th toe	Splint, 5 days	2	6	Excellent

* Average period of disability: 9 days.

FINGERS

Case	Age	Fracture	Other Treatment	Injections	Days, Disability*	Result
M. L.	37	Middle phalanx 4th fing.	Hairpin splint	1	16	Good
M. P.	37	Distal phalanx 4th fing.	Splint, 13 days	1	14	Good
J. M.	25	Chip-fracture, middle phalanx 2nd finger.	Splint, 2 days	3	7	Excellent

* Average period of disability: 12 days.

TABLE V

FRACTURES OF THE UPPER END OF THE HUMERUS

Case	Age	Fracture	Other Treatment	Injections	Days, Disability*	Result
J. B.	55	Surg. neck and greater tuberosity	Axillary pad, 3 days; sling	3	21	Excellent
L. G.	59	Surg. neck and greater tuberosity	Hanging case, 4 weeks	3	35	Excellent
E. H.	60	Greater tuberosity	None	2	21	Excellent
M. F.	48	Surgical neck	Hanging case, 4 weeks	1	42	Fair
F. M.	71	Surgical neck	Body swathe	1		Unsatisfactory†
E. W.	65	Surgical neck	Body swathe	1	42	Fair

* Average period of disability: 32 days.

† Follow-up, 5 months later: Patient able to put hand on the top of head.

dressing was used for a time, but was discarded as soon as the patient would use the arm. The best results were obtained in private patients, who would cooperate by making an effort to resume active function. All cases had good end-results. Three, with fractures of the greater tuberosity, had almost 100

A. B.

FIG. 3.—(A) Bimalleolar and posterior marginal fracture. Plaster splint for six days; three procaine injections; elastic-adhesive bandage. Went on trip and was walking well, thirteenth day; played nine holes of golf and danced the third week. (B) "Can hardly tell which ankle was broken," February 17, 1941.

FIG. 4A. FIG. 4B. FIG. 4C.

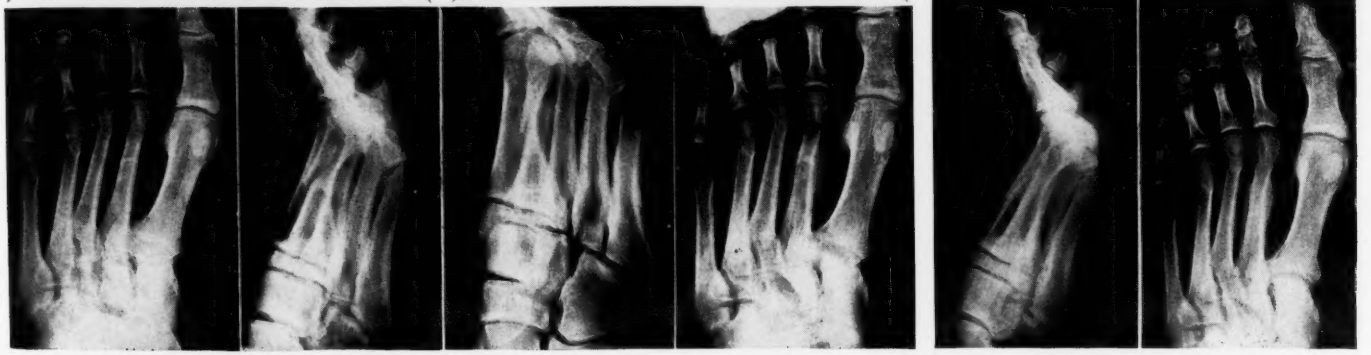


FIG. 4.—(A) Fracture of second metatarsal, October 3, 1940. Injected with procaine and foot strapped; patient bowled the same evening, wore his usual shoes, and lost no time from work. One reinjection and two restrappings. (B) Rapid calcification of callus, October 30, 1940. (C) Follow-up, January 28, 1941.

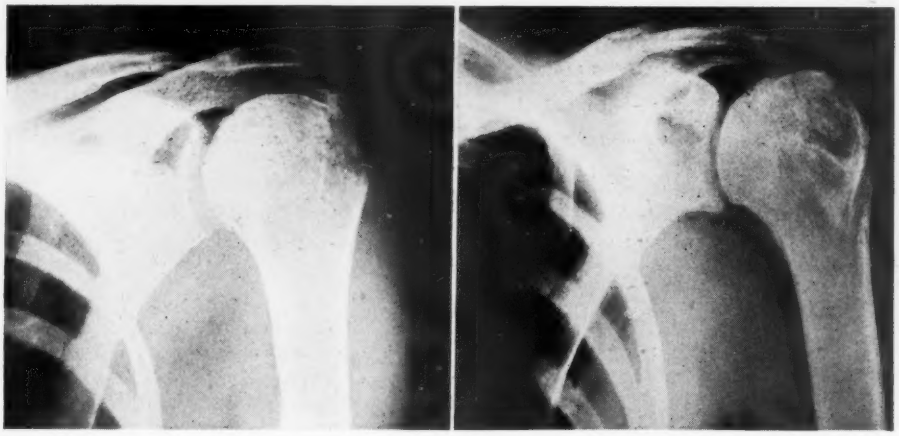
per cent shoulder function within two and one-half months after injury. In our experience, this is quite unusual for this type of fracture in the older age-group (Fig. 6).

Fractures around the Elbow.—There were nine patients with fractures in the region of the elbow; two of these were bilateral, making 11 fractures (Table VI). The limitation of motion which follows the immobilization of these fractures does not appear when active function is permitted during the early stages of fracture healing. The average period of disability of the elbow was ten days in these 11 fractures. Exceptional results were noted in four fractures of the head and neck of the radius. All cases obtained almost normal functional results in eight to 12 days.

We have had no instance of an ossifying hematoma appearing in the small series treated by this method (Fig. 7).

FIG. 5A and B.

FIG. 5.—Treated by splint elsewhere; had continued pain. (A) Roentgenogram, September 4, 1940, one month after fracture shows no union. Splint removed; injected with procaine, toe strapped. Played in tennis tournament three days later. (B) Follow-up roentgenogram, April 8, 1941.



A. B.

FIG. 6.—(A) Fracture of greater tuberosity, January 31, 1941. Three procaine injections and active mobilization of arm and shoulder. (B) Full normal function, April 12, 1941.

his usual shoes, and lost no time from work. One reinjection and two restrappings. (B) Rapid calcification of callus, October 30, 1940. (C) Follow-up, January 28, 1941.

TABLE VI

FRACTURES ABOUT THE ELBOW

Case	Age	Fracture	Other Treatment	Injections	Days, Disability*	Result
H. Y.	41	Int. epicondyle humerus	None	2	11	Good
H. M.	21	Ext. epicondyle humerus	Sling	4	9	Excellent
P. A.	20	Int. epicondyle humerus	Sling	1	10	Good
D. C.	3	Condyles both humeri	None	0	10	Excellent
R. E.	48	Malunion—old callus	Splint, 2 days. Sling, 2 weeks	2	14	Excellent
A. B.	40	Neck of radius	Splint, 10 days	2	12	Excellent
J. K.	9	Neck of both radii	None	1	9	Excellent
J. R.	28	Head of radius	None	1	8	Excellent
D. F.	23	Olecranon	Splint, 2 days	1	2	Good; incomplete follow-up

* Average period of disability: 10 days.

FIG. 7.—Pain and slight swelling over head of radius; inability to flex or extend elbow or rotate forearm. Procaine injection, 20 cc. of 1 per cent solution; no immobilization. No spontaneous pain the following day; ten days later, almost complete function of elbow; driving his car.

Fractures of the Lower End of the Radius.—The five fractures of the lower end of the radius were all so-called check- or crumble-fractures, with fracture of the styloid process (Table VII). However, there was consider-

TABLE VII

FRACTURES OF THE LOWER END OF THE RADIUS

Case	Age	Fracture	Other Treatment	Injections	Days, Disability*	Result
M. S.	49	Styloid of left radius	Splint, 6 days	1	11	Good
D. C.	45	Radial styloid	Splint, 2 days	1	7	Excellent
M. W.	69	Radial styloid	Splint, 1 day	1	10	Excellent
G. H.	58	Radial styloid	Splint, 9 days	2	14	Excellent
M. F.	—	Radial styloid	Splint, 6 days	1	8	Excellent

* Average period of disability: 10 days.

able edema, pain, and disability present, although there was no displacement. In other words, these were cases which would probably have been diagnosed a bad sprain before the days of roentgenography.

One patient, age 45, with a check-fracture of the radius and a chip-fracture of the cuneiform, was injected with procaine after four days' immobilization on a hand-splint. On removal of the splint, any voluntary motion of the fingers was painful. She was unable to pick up her pocket-book. Immediately after injection, she was able to pick up objects. Three days later she was able to use her hand. She had not experienced the usual after-pain. Six days after injection, all swelling had disappeared; the patient had no pain, but there was still slight tenderness over the radial styloid. One month later, function was excellent, and there was no pain present.

TABLE VIII

FRACTURES OF THE METACARPALS

Case	Age	Fracture	Other Treatment	Injections	Days, Disability*	Result
F. D.	18	1st metacarpal	Encasement	1	21	Unsatisfactory
T. D.	39	2nd metacarpal	None	2	4	Excellent
P. T.	48	5th metacarpal	Encasement	1	28	Unsatisfactory
E. H.	33	5th metacarpal	Splint, 8 days	1	10	Excellent
G. S.	19	5th metacarpal	Splint, 4 days	1	14	Good
J. P.	21	5th metacarpal	Splint, 3 days	1		Incomplete follow-up
A. F.	23	5th metacarpal	None	1	25	Excellent

* Average period of disability: 17 days.

Metacarpal Fractures.—Metacarpal fractures vied with those of the ribs in giving the least satisfactory results (Table VIII). This was probably due to improper selection of cases, as both cases we listed as unsatisfactory had some displacement of the fragments and reduction should have been attempted immediately. After failure, these were treated in a plaster encasement, following an attempt to improve the position of the fragments. Both of these cases eventually obtained a quite satisfactory end-result. Excellent results were obtained in fractures without displacement by injection and early mobilization.

TABLE IX

FRACTURES OF THE CLAVICLE

Case	Age	Fracture	Other Treatment	Injections	Days, Disability*	Result
O. D.	25	Tip of clavicle	None	1	3	Excellent
M. F.	23	Tip of clavicle	None	1	2	Excellent
J. L.	69	Shaft	Plaster Fig.-of-8	1	5	Good
B. S.	56	Shaft	Plaster Fig.-of-8	1	6	Good

* Average period of disability: 4 days.

FRACTURES OF THE RIBS

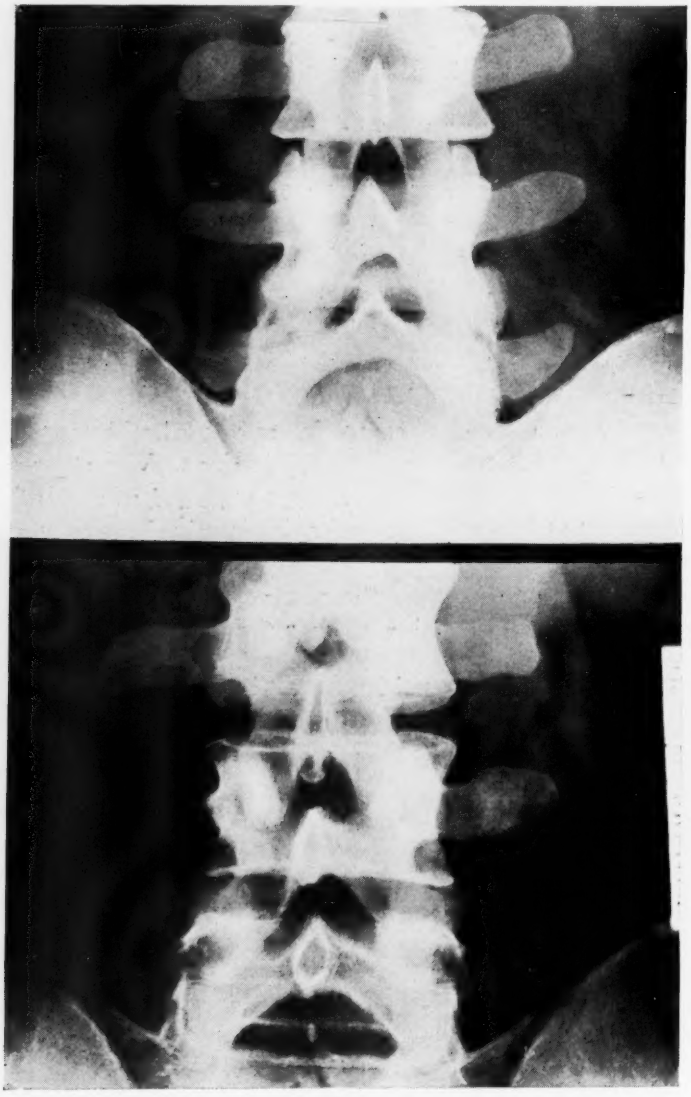
Case	Age	Fracture	Other Treatment	Injections	Days, Disability*	Result
W. S.	60	12th rib	Strapping, 2 days	1	7	Fair
N. K.	51	7th rib	Strapping, 2 days	2	2	Fair
M. D.	53	7th rib	Strapping, 11 days	2	14	Good
L. G.	30	8th rib	Strapping, 2 days	1	4	Good
D. A.	47	7th rib	Strapping, 14 days	2	55	Unsatisfactory

* Average period of disability: 16 days.

Clavicle and Rib Fractures.—Except for two fractures of the tip of the clavicle, injection and mobilization seemed to have little more to offer than

other types of treatment which permit early function. However, our experience was rather limited. Also, fractured ribs did not give as good results as we had anticipated (Table IX). Certainly they are ideal, theoretically, for this form of therapy. Most of these patients were very heavy, and possibly our lack of success should be attributed to improper technic rather than method. A patient who had disability for almost two months was promptly relieved by regional nerve block with procaine and alcohol, as recommended by Rovenstine and Byrd.[11]

A.



B.

FIG. 8.—Fracture of left transverse process, fourth lumbar vertebra. Four procaine injections and adhesive strappings. (A) Roentgenogram, 18 days after fracture; early callus. Patient returned to work, as an inspector, on fourth day after fracture. (B) Follow-up roentgenogram, seven weeks after fracture; no disability.

TABLE X

MISCELLANEOUS FRACTURES

Case	Age	Fracture	Other Treatment	Injections	Days, Disability	Result
R. G.	36	Left transverse process, 4th lumbar vert.	Strapping	5	11	Excellent
F. S.	40	Transverse processes, 2nd & 3rd lumbar vert.	Strapping	3	13	Good
E. B.	2	Both bones forearm	None		17	Excellent
J. M.	56	Shaft of fibula	Gelatin boot	1	15	Good

Miscellaneous Fractures.—Two cases of fracture of the transverse process of lumbar vertebrae gave excellent results (Table X). This is a fracture

FIG. 9.—Fracture of both bones of forearm. First seen 11 days after fracture. Note early callus. No immobilization; no injection because patient had no pain. Excellent union with slight deformity; normal function.

that certainly has been overtreated. It is hard to conceive how this fracture can be immobilized under any circumstance, either by bed rest or the application of a plaster encasement. The following case illustrates the therapy in these cases:

Case Report.—On January 5, 1941, a male, age 36, fell, striking the lower back on a block. There was tenderness over the third and fourth transverse processes and erector spinae muscles. The patient was injected and strapped on January 8, 1941. This was repeated on four occasions, the last injection being given on January 29, 1941. He returned to work the day after the first injection. Slight discomfort was present until February 18. Follow-up examination, March 26, showed no symptoms and the patient could move his back in all directions without discomfort (Fig. 8).

COMMENT.—Callus formation does not appear to have been delayed in these cases. As a matter of fact, one is impressed by the early formation of callus. We wish to cite two cases who were treated only by mobilization:

Case 1.—A male, age two and one-half, fell from a scooter on February 7, 1941, injuring both arms. Roentgenograms, February 10, showed a fracture of the external condyle on the left, and of both condyles on the right side. There was no displacement and, in view of the fact that the child was uncooperative and it would have been extremely difficult to adequately immobilize these fractures, the arms were simply mobilized. One week later, the child used the arms without apparent pain. Roentgenograms, February 24, only 17 days after injury, showed excellent callus formation. Final examination, March 3, showed excellent function, although flexion was still slightly limited.

Case 2.—A child, age two, fell from a chair, January 12, 1941. The mother treated the arm with applications of Epsom salt. Because of slight deformity in the arm, the child was brought into the hospital. Roentgenograms showed fracture of both bones of the forearm, with callus formation 11 days after injury (Fig. 9). The arm was splinted. All splints were removed in five days. Final examination, February 12, showed no pain, tenderness, or discoloration. Slight angulation was present.

From these two cases, one might assume that the most important factor in this method of treatment is mobilization, and one might question whether the procaine has any benefit. There were nine cases in this series which were seen late, an average of 19 days after injury; the shortest time elapsed was ten days and the longest, 50 days. All these cases complained of pain and disability. They were all relieved by procaine injection sufficient to permit resumption of active function. This would tend to prove that mobilization is not the only factor.

SUMMARY AND CONCLUSIONS

The methods employed and the results obtained in 84 fractures treated by this method are reported. The results were unsatisfactory in only four cases, and in no case was the eventual end-result impaired by an attempt at this method of therapy.

Many minor fractures are best treated by early mobilization and procaine injection. The procaine injection at the site of fracture or into the sympathetic ganglia interrupts the reflex which produces vasomotor changes, edema, and pain at the injured site. Early mobilization is thereby permitted, and rapid and excellent fracture healing results. The period of disability is reduced and the eventual end-result is improved in many instances, especially in articular fractures.

Only fractures which do not require reduction in non-weight-bearing bones can be treated by this method.

The author wishes to acknowledge the kindness of Dr. Eugene P. Pendergrass, Professor of Radiology at the University of Pennsylvania Hospital, for the roentgenograms used in this study.

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THREE YEARS' EXPERIENCE WITH VITALLIUM IN BONE SURGERY*

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IN OCTOBER, 1936, we[1] first described the effects of electrolysis on metals in bone and showed by our research that electrolysis was the principal cause of failure of metal appliances in bone. While conducting these experiments, we found only one alloy among all those tested that was completely passive (electrically inert) in the presence of body fluids, that caused no pathologic changes in bone, and that was not itself corroded. This alloy, Vitallium, composed of cobalt, chromium, and molybdenum seemed so inert that we recommended its use in bone surgery. Since then, Vitallium appliances have been widely used over a sufficient period of time to justify a statistical study of the value of this new alloy. Sixty-one surgeons in various parts of the country who have used Vitallium appliances cooperated with us in the following analysis which is based on a total of 1,227 cases.

These 1,227 cases do not include more than 200 patients in whom Vitallium hip cups have been used, or those instances where Vitallium orbital implants were utilized, but are those in which nails, screws, plates, *etc.*, were placed in bone to treat various fractures. For fractures of the neck of the femur, 23 surgeons used Vitallium Smith-Petersen nails, two used hip screws, two used lag screws, and three used plain Vitallium nails, without a single case of extrusion of the nails. The 1,227 fractures treated with Vitallium appliances included fresh fractures, old fractures with delayed or nonunion, compound fractures, and old cases where Vitallium screws were used to secure bone grafts. In all these varying conditions, and in the hands of many surgeons, 1,136, or 92.6 per cent of the cases, obtained solid bony union while 47, or 3.8 per cent, had delayed union, and only 44, or 3.6 per cent, developed nonunion. Many of these cases were those wherein there was much trauma or where the fractures were originally compounded.

Vitallium, of course, has no stimulative effect on the healing of bone but it is distinctive among metals in that it has no retarding effect. With such an absolutely nonelectrolytic alloy, it is possible to plate certain fractures or nail fragments securely without fear of erosion of bone about the metal appliances. The permanent immobilization of fragments which can be gained with this inert material insures rapid and solid healing of fractures. Metal nails in the hip have completely revolutionized the outlook for patients with fractures of the neck of the femur and the possibility of union is much greater when

* Presented before the Texas Surgical Society, Dallas, Texas, April 1, 1940.

there is no erosion of bone about the metal (Fig. 1). Similarly, metal plates are invaluable in other troublesome fractures such as those in both bones of the forearm, the shaft of the humerus, or the upper end of the shaft of the femur.

For years, there has been much apprehension about the use of metal appliances in fractures because surgeons have observed many failures after they have placed highly electrolytic alloys in the bone. The subsequent electrolytic destruction of metal and bone caused the operations to end unsuccessfully and convinced the surgeons that metals cannot be used in the body with any degree of safety. Loosening of appliances, discoloration of tissues, and accumulations of sterile fluid caused by "electrolytic osteitis" were attributed to infection, faulty technic, or some vague foreign body irritation.

FIG. 1.—Photograph of neck of the femur where a stainless steel nail has been in the bone about eight months. Note deposits of metal in the head of the bone and absorption of cancellous bone along the path of the nail. (From Felsenreich: Arch. f. klin. Chir., 195, 30, 1939.)

Failures with Vitallium Appliances.—The original dental Vitallium alloy, with which we first experimented, was found to be too brittle and weak for fracture work. Shortly after we recommended its use in surgery, other surgeons also complained of the same defects in the material. Consequently, at our suggestion, the manufacturers of Vitallium modified the structure of the alloy to give it strength and toughness while retaining its remarkable passivity in body fluids.

Even so, for all the early cases with broken plates and screws, they constitute but a very small per cent of the successes with Vitallium appliances. Out of 1,227 cases, of all types, there were 11 instances in which a plate broke, or 0.089 per cent of the total. Ten screws broke, or 0.081 per cent of the total. Four plates bent, or 0.033 per cent of the total. Two nails bent, or 0.016 per cent of the total. One hip screw bent, or 0.008 per cent of the total. In other words, 1,199 of the cases, or 97.7 per cent of the total, had no technical trouble from the application of the metal.

Bent or Broken Plates.—In 1937, the first year Vitallium was generally used, several surgeons found that plates bent or broke even though the extremity was well supported externally. In these instances, the metal was at fault because it was too brittle at the outset. Also, the early flat plates were made too light and the Lane-type plates were too narrow. This has now been corrected by making heavier appliances of Vitallium more malleable,

so that plates may be bent to fit an irregular surface without danger of breaking and they will not bend or break if an extremity is handled with reasonable caution.

Of course, no Vitallium or any other metal plate is strong enough to immobilize a fractured long bone without additional external support by plaster encasement or splint. Unless adjacent joints are immobilized by such splints, there is always the possibility that the fragments may move or that some undue strain will detach the appliance from the bone. The tensile strength of a nail, screw, or plate is not an important factor since it is only called upon to hold bone fragments together in normal alignment. The support of the entire extremity and the protection against muscle pull must be provided by plaster encasements and splints in addition to the plates attached to the bone.

Screws which erode bone by "electrolytic osteitis" are like screws in decaying wood that lose their hold and thus fail in their purpose. Just as it is important to keep screws and wood dry to prevent loosening, so is it necessary that screws in bone must be nonelectrolytic to prevent erosion of bone. Consequently, no metal plates and screws are absolutely dependable for immobilizing fractures unless they are totally passive (nonelectrolytic) in the body.

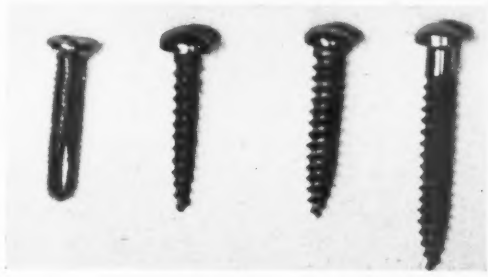

FIG. 2.—Photograph of various types of Vitallium screws. (Machine-type screw which cuts its own thread in the bone. First wood-type screw with too small a shank. Newer wood-type screw with threads to the head for use with plate. Wood-type screw with smooth shank for tightening fragments.)

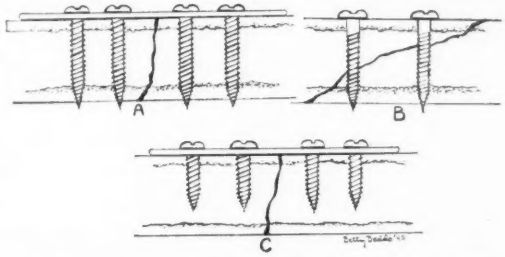

FIG. 3.—Diagram of bone with plate and screws inserted. (A) Long screws engaging both cortices giving best support. (B) Screws with unthreaded shank used to pull oblique fracture together. (C) Short screws engaging only one cortex.

Vitallium is so hard that plates, nails, and screws must be cast and this process is costly. Its strength is not as great as some of the stainless steels but it possesses, in its present composition, all the strength needed to immobilize bone fragments which are properly supported externally. Certainly, an alloy which is absolutely passive, and hence nonirritative, and which can be used by many surgeons with 97.7 per cent success, fulfills the requirements of an almost perfect material for the internal fixation of fractures.

Bent or Broken Screws.—The first Vitallium wood-type screws were made with a thin shank which was too fragile and which broke quite easily (Fig. 2). This has been corrected by making a heavier screw of tougher metal and with a stronger shank. The screws with threads which extended to the head were

designed for use with a plate, while those in which part of the shank was unthreaded were made for pulling fragments together. Naturally, if the former type of screw is used for this purpose the drill-hole in the proximal fragment must be larger than the diameter of the thread. Improper screws or those used incorrectly would naturally tend to break (Fig. 3).

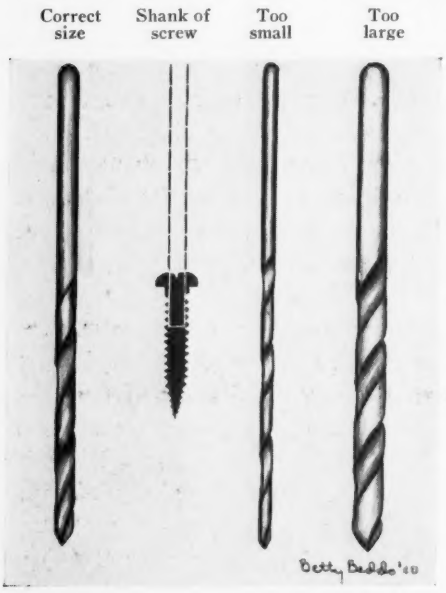

FIG. 4.—Diagram demonstrating correct size of drill to use in making screw-hole. Drill must be exact diameter of the shank of the screw.

Many surgeons complained of difficulty in using the machine-type screws with the cutting edge which is supposed to make a path for the thread in the bone. When such a screw is cast of Vitallium, the thread is not sufficiently sharp to cut the bone easily. Also, such screws, without a taper point, are difficult to insert. Therefore, we feel that the machine-type screw of Vitallium is not nearly so successful as the plain wood-type or coach-type screw.

A rather obvious cause of failure in placing screws in the bone is disproportion between the size of the screws and the caliber of the hole in the bone (Fig. 4). The drill-hole should have exactly the same diameter as the shank of the screw. If the hole is larger than the shank, the threads do not engage deeply enough in the bone to secure a good purchase and the threads are easily stripped when the screw is finally tightened. If the hole is smaller than the shank, great force is required to drive the screw home and this causes slipping of the screw driver, breaking of the head of the screw, or inability to tighten the screw against the plate.

Another common cause of failure in inserting screws in bone is carelessness in the depth of the holes drilled. Even if a screw is not long enough to pass through both cortices of the bone, the hole should be drilled deep enough so that the tip of the screw does not strike bone. It is a safe rule to drill holes through the entire bone so that the screws have ample clearance. Longer screws provide stronger support than shorter screws and screws which engage both corticles of a long bone provide better anchorage than screws in one cortex alone. If long screws are used, holes should pass entirely through the bone to permit the ends of the screws to project on the opposite side.

Should Vitallium Appliances Be Removed?—While we ordinarily do not remove Vitallium appliances after fractures have healed, some surgeons prefer to because they hesitate to leave "foreign material" in a bone. This atavistic idea originates from the old fear of irritative reactions about metals in the

body. Previously, metals were used which caused "electrolytic osteitis" of bone with occasional breaking open of wounds, draining sinuses, and in some cases, late fracture. Vitallium, which causes no reaction at any time, can be left indefinitely in the body with no danger of late tissue damage. It has been pointed out that many old metal appliances or pieces of metal have been left in the body for years without causing symptoms. This is true but it is probably due to the fact that these metals became encapsulated in dense fibrous tissue which prevented body fluids from coming in contact with them, or they developed a protective molecular veil ("oxygen film") which reduced electrolytic activity. In any case, wounds have healed in spite of their presence.

FIG. 5.

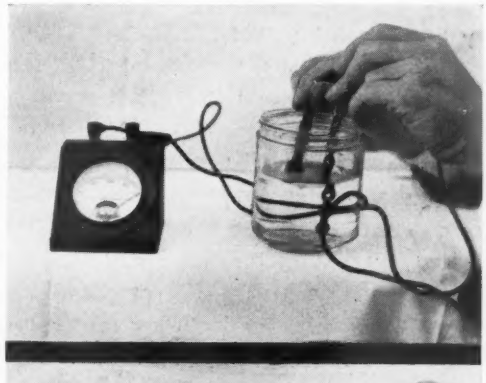

FIG. 6.

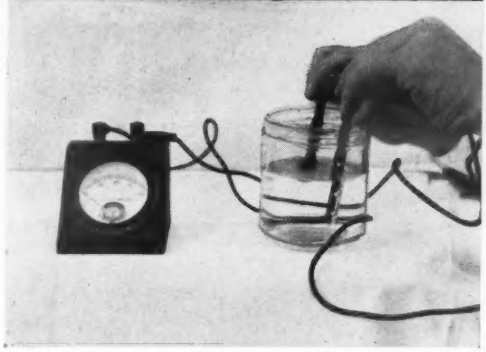

FIG. 5.—Photograph of micro-ammeter coupled with stainless steel plate in saline solution. Note that maximum current is produced.

FIG. 6.—Photograph of micro-ammeter coupled with Vitallium plate in saline solution. Note that no current is produced and the micro-ammeter registers zero.

In this series of 1,227 cases, Vitallium appliances were removed in 87 instances after the bone was healed and the need for them no longer existed. Every observer reported that the screws and plates were bright and untarnished and that the tissues about them were normal in appearance. Where there was no infection or other complications, the screws were tight in the bone and force was required to remove them. In other words, there was no evidence of the slightest erosion of bone or of any irritation of soft tissue from the presence of the Vitallium metal. In general, roentgenograms of the Vitallium appliances revealed no changes in the bone about the metal at any time after they were inserted. As Smith-Petersen remarked, "Vitallium seems to be as inert in the body as a piece of glass." Others stated: ". . . Vitallium causes the least irritation of any metal we have ever used . . ."; or ". . . even in soiled bone the soft parts healed around the plates in an astonishing manner."

Infected Wounds.—Of these 1,227 operations, where Vitallium was used, 55, or 0.044 per cent, were followed by infected or draining wounds. Of these, 46 were cases of severely compounded fractures that had been plated, one was a relighting-up of an old infected hip, and one was in a patient with phlebitis and cystitis. In the remaining seven cases, each surgeon stated that

the subsequent infections were "not attributable to the metal" and that when screws were loose it was due to the infection.

Vitallium appliances not only did not cause infections in the bone but, in several instances, infected wounds gradually healed around the metal. Many surgeons, including ourselves, have applied Vitallium plates to fresh compound fractures and have seen the fractures and skin wounds heal by first intention. This advance in fracture treatment has done much to prevent the usual deformities and delayed unions after compound fractures.

CONCLUSIONS

(1) Metals which are nonelectrolytic (passive) in body fluids cause no pathologic reactions in the tissues. Vitallium which is completely passive is more inert than any alloy that has been developed so far.

(2) 1,227 Vitallium appliances used by 61 surgeons, in various parts of the country, resulted in 92.6 per cent solid bony union of fractures, 3.8 per cent delayed union, and 3.6 per cent nonunion.

(3) When Vitallium was first introduced, it was not strong enough or sufficiently malleable for general use. These defects have been corrected. In spite of former faults in the material, breaking of plates and screws occurred only 28 times in a series of 1,227 cases, or only 2.3 per cent of the total. This percentage has steadily decreased as the alloy has been improved.

(4) Screws made of Vitallium were originally too fragile for all uses. The new screws are amply strong for any type of operation and the wood-type screw has been found to be most satisfactory.

(5) On the occasions when Vitallium appliances have been removed, the surrounding bone has shown no erosion or discoloration.

(6) When infections occurred in any cases in this series, they could be traced to such causes as compound injuries, septicemia, *etc.* In other words, no wound became infected *because* of a Vitallium appliance.

(7) On the basis of this study, it has been found that Vitallium has sufficient strength and inertness to be perfectly suited to all requirements of bone surgery.

(8) In metals or alloys the phenomena of passivity are apparently closely linked to their degree of inertness under corrosive conditions, and comparative determinations of current flow with a micro-ammeter, using some common third metal as an anode, give useful indications of their probable tendencies toward reaction *in vivo*. Metals or alloys that give relatively high readings are likely to cause a corresponding disturbance in bone or tissue. Above all, two metals or alloys of different character must be avoided, such as a plate of one kind and screws of another, in the same operation.

(9) In any new metal, tensile strength, hardness, shape of appliances, *etc.*, are all comparatively unimportant and secondary to the vital fact that the material must be passive (nonelectrolytic) in the tissues.

(10) A great deal of study and development is going on in the field of

stainless alloys. The theoretical work of Uhlig and Wulff at M.I.T. has thrown additional light on passivity, and disclosed the limitations of the oxide film protection theory. This newer conception which deals in terms of the structure of the atomic lattice shows, more rationally, the importance of the rôle of hydrogen in the loss of passivity and explains why the addition of molybdenum to the 18–8 type of material, has increased its resistance to corrosion attack, particularly of the localized form resulting in pits. Maybe it is possible that further developments will produce material more suitable than the best of the present available stainless steels.

(11) We will continue our search for an ideal alloy for use in the body and enlist the aid of chemists and metallurgists to help discover such an alloy. We hope some material can be discovered which has the proper strength, ductility, and passivity for all uses in the body. So far, Vitallium is the only metal we have found which is completely passive in body fluids. The final choice of material must possess such complete passivity.

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BRIEF COMMUNICATION

A SIMPLIFIED ARTHROMETER

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FOR SIMPLE and more accurate measurement of joint position and motion, the writer, for several years, has employed the pocket instrument illustrated in Figure 1. The construction is such that the indicator retains a fixed horizontal position, and rotation is directly denoted in degrees on the graduated dial face. The operation and application of the instrument will be obvious from the illustrations. It can be applied to virtually every position and motion of the body, and has been useful in estimating obliquities of the pelvis, shoulders, and trunk (Fig. 2).

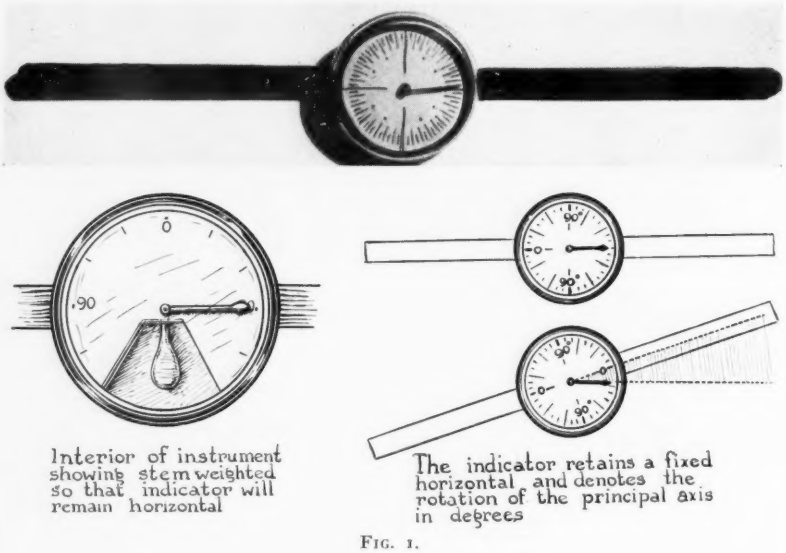

FIG. 1.

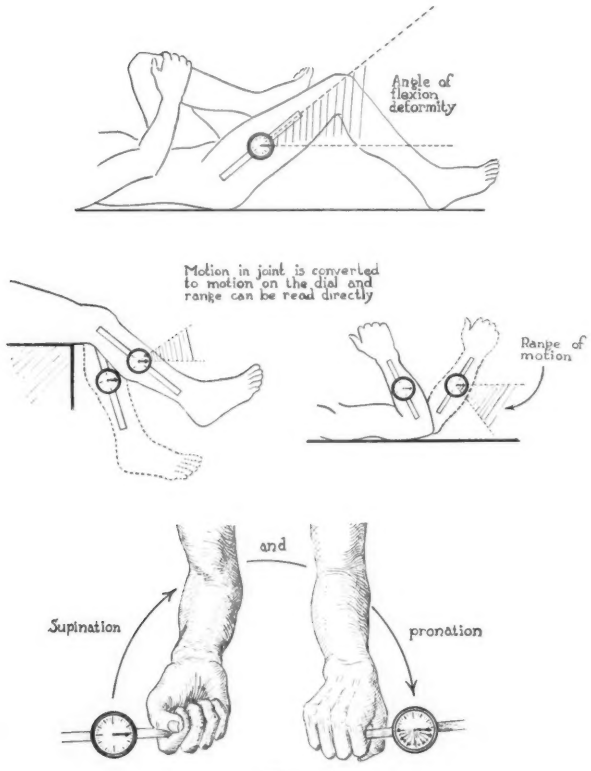

FIG. 2.

BOOK REVIEWS

OPERATIVE SURGERY. By J. SHELTON HORSLEY, M.D., LL.D., F.A.C.S., Richmond, Va., and ISAAC BIGGER, M.D., Richmond, Va. St. Louis, Mo.: C. V. Mosby Co.

THIS is the Fifth Edition of a standard textbook of "Operative Surgery" by Doctors Horsley and Bigger, which was first published in 1921. But three years have elapsed since the appearance of the Fourth Edition, but no one will take issue with the authors' statement that such rapid progress is now taking place in surgery that a revision at this time was indicated. As in the Fourth Edition, the book appears in two volumes, which are a credit to the publisher and add new laurels to the illustrator, Helen Lorraine.

In the preface one finds outlined the newer procedures which have been added, such as ligation of the patent ductus arteriosus, segmental pneumonectomy, and extrapleural pneumothorax. But this does not speak of the careful reediting which is evident upon almost every page of the book when one compares it with the previous edition.

The chapter on peritonitis has been almost completely rewritten and now occupies 28 pages, and there has been a similar editing of the chapter on appendicitis, which is very greatly expanded.

In this work they still carry a section on orthopedics, which is gradually being deleted from the textbooks on general surgery, and while it maintains its former high standard, the accepted technics of practically all the newer procedures in orthopedic surgery are now included.

The illustrations throughout the entire book maintain the uniform perfection which has been so characteristic of this textbook from its First Edition, and these illustrations are a great asset to those of us who are more visually minded than word minded.

That the authors have accomplished their objective, and have brought this long recognized standard textbook of "Operative Surgery" up to date will be evident to any one fortunate enough to possess a copy.

All concerned in the reediting of this work are to be congratulated upon this addition to our surgical literature.

WALTER ESTELL LEE, M.D.

DISEASES OF THE ESOPHAGUS. By PORTER B. VINSON, M.D., Professor of Bronchoscopy, Esophagoscopy and Gastroscopy, Medical College of Virginia. Springfield, Ill.: Charles C. Thomas Co., 1940.

VINSON, in a monograph on diseases of the esophagus, presents, for the first time, a discussion of the diagnosis and treatment of esophageal lesions in book form. The need for such a book becomes apparent when one considers the variety of conditions which are overlooked at the present time, and when prepared by one with such experience in this specialty, it can be accepted as authoritative, and should provide a useful guide not only for the specialist, but also for the general practitioner. It would seem to the reviewer that this is just what Vinson has accomplished.

The book, as all products of the publishers, Charles C. Thomas Co., is worthy of the text, with its clear, large type, excellent illustrations, and a generous use of line drawings which serve to supplement unusually well-reproduced roentgenograms and photographs.

The table of contents starts with the general management of the patient, and in 16 chapters adequately covers the subject, concluding with an evaluation of the present status of gastrostomy.

Among the highlights are the discussions of the congenital, malignant and traumatic lesions; the various diseases; and the foreign bodies which one should consider in patients who experience difficulty in swallowing.

A carefully made and not too fulsome bibliography at the end of each chapter is a real asset to the text.

Specifically, the author emphasizes the fact that 90 per cent of lesions of the esophagus may be accurately diagnosed without the use of the special examinations and instruments which he discusses, and he warns against the danger of stressing the importance of these special procedures, making a plea for a careful routine general examination, which, in addition to making unnecessary special examinations in a large number of cases, should always be coordinated with the special procedures.

He very properly calls attention to the fact that marked emaciation associated with esophageal obstruction is not necessarily due to malignancy, but very frequently is the result of starvation and dehydration only. Further, as a result of the dehydration which follows esophageal obstruction of any kind, surgical procedures are followed by a very high mortality rate, averaging 50 per cent. This, however, may be lowered if the required fluids are provided preoperatively. He claims gastrostomy should never be considered as a minor procedure, for it is followed by an unexplainable mortality—10 to 15 per cent, and should always be preceded by putting the patient in water and electrolyte balance preoperatively. In addition to the mortality rate, it carries a hospitalization of from 10 to 14 days. Further, he is very pessimistic about the results that may be expected in gastrostomy, and claims it is not palliative in malignant obstruction, while in benign obstruction the stricture may become complete, unless routine dilatation is carried

on, which is made possible by the swallowing of a string which will act as a guide for the passage of a sound.

It is startling to read that in approximately 40 per cent of patients suffering with difficult swallowing, the obstruction is the result of carcinoma, which in approximately 5 to 7 per cent of all carcinomatous lesions involves the esophagus. No exception can be taken to his claim that an accurate diagnosis of malignancy can be made only by biopsy, and then by a pathologist who is experienced in the handling of small pieces of tissue, but we cannot fully agree with his pessimistic attitude about the value of gastrostomy in hopeless malignancy, especially in those cases in which it is impossible to pass a stomach tube through the lumen of the obstructing growth. In our experience, approaching death has not been so horrible when we have been able, with a gastrostomy, to avoid the throes of starvation and thirst.

The subject of esophageal diverticula is given due consideration, and the value of the guidance provided by the swallowed string is emphasized. With this procedure a catheter can usually be guided past the opening in the lateral wall of the esophagus into the sac. This is the procedure which has been employed by Jackson for many years and is one of the basic principles of his use of the esophagoscope in the one-stage operation. Vinson, however, seems to be unable to decide between the prehistoric two-stage operation of excision, which was first advocated by Moynihan, and the one-stage procedure which has been made possible by Jackson's cooperation with the esophagoscope. Those who have had experience with the one-stage technic are definitely convinced that this procedure is applicable in all types of pulsion diverticula, provided the esophageal lumen can be maintained during the process of isolation of the sac, and that angulation of the esophageal wall is prevented. Such protection, in our experience, can be supplied only with the esophagoscope or a stiff stomach tube.

The future of gastrostomy, Vinson feels, is now assured, but for the present, at least, we must consider that direct visualization of the lining of the stomach is but one method of diagnosis—and we would like to add that it should be correlated with other accepted routine diagnostic procedures. He wisely warns that a negative gastroscopic examination is of little value—and again we add that a positive one should be in agreement with other clinical findings in order to be accepted at par value. His inclusion of this subject, and the limited space devoted to it, would seem to merely emphasize its possibilities, and he very properly refers his readers to Rudolph Schindler's book on "Gastroscopy" for an adequate presentation of this field.

WALTER ESTELL LEE, M.D.

ABDOMINAL OPERATIONS. By Rodney Maingot, F.R.C.S., England, 2 vols., 8°, pp. 1385. Appleton-Century, New York and London, 1940.

Mr. Maingot's work is not restricted to a consideration of operative technics. The two volumes cover the surgical problems of the abdomen with the same completeness of detail found in many of the longer systems of surgery. Incidence, classification, pathology, etiology, diagnosis, pre- and postoperative care and prognosis are discussed almost as fully as operative technic. Important references are conveniently cited in the text.

As with most texts by individual authors, some sections are more brilliantly written than others. The section on liver abscess seems particularly well done. In the section on appendicitis nearly all phases of the disease are thoroughly discussed except for the postoperative management of patients with spreading peritonitis. This subject, which is the crux of the problem of appendicitis mortality, is all but omitted. The important subject of chemotherapy is not adequately discussed either in relation to appendicitis or to colon resections. The use of the Miller-Abbott tube is mentioned but the technic of its use is omitted and the indications and contraindications for its employment are not considered in appropriate detail.

Despite these omissions, however, the work as a whole is comprehensive and a high standard of conciseness and clarity is maintained both in the text and in the illustrations. It should be very useful for those who require a thorough discussion of the general surgical problems of the abdomen without requiring a complete system of surgery.

JONATHAN E. RHOADS, M.D.

CORRESPONDENCE

THE EDITORIAL BOARD, ANNALS OF SURGERY, June 23, 1941.
J. B. LIPPINCOTT COMPANY,
227–231 South Sixth St.,
Philadelphia, Pa.

Dear Sirs:

It has been brought to my attention that, in discussing a paper read by Dr. Wm. F. MacFee on "Hernia" at the annual meeting of the American Surgical Association held in St. Louis in 1940, I misquoted Doctor Burdick and Doctor Coley to the effect that they had stated that they had failed to master the technic of using fascia and had suggested as a substitute the removal of the testis and spermatic cord. This I regret exceedingly as their papers show that no such interpretation of their statements was justifiable. I shall be very glad indeed if you will give this note the publicity necessary to counteract any misconception of their views that my remarks may have caused.

Yours sincerely,
W. E. GALLIE, M.D.

EDITORIAL ADDRESS

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East Washington Square, Philadelphia, Pa.